

8 20 26 ADDRESS - PHONE NOS.
30 36 54 58 ADDRESS 68
40

ELEKTOR ELECTRONICS

THE INTERNATIONAL
ELECTRONICS MAGAZINE

April 1995
£ 2.45

Focus on:
Microcontroller
development systems

STEPPER MOTOR CONTROL

Electronic
barometer

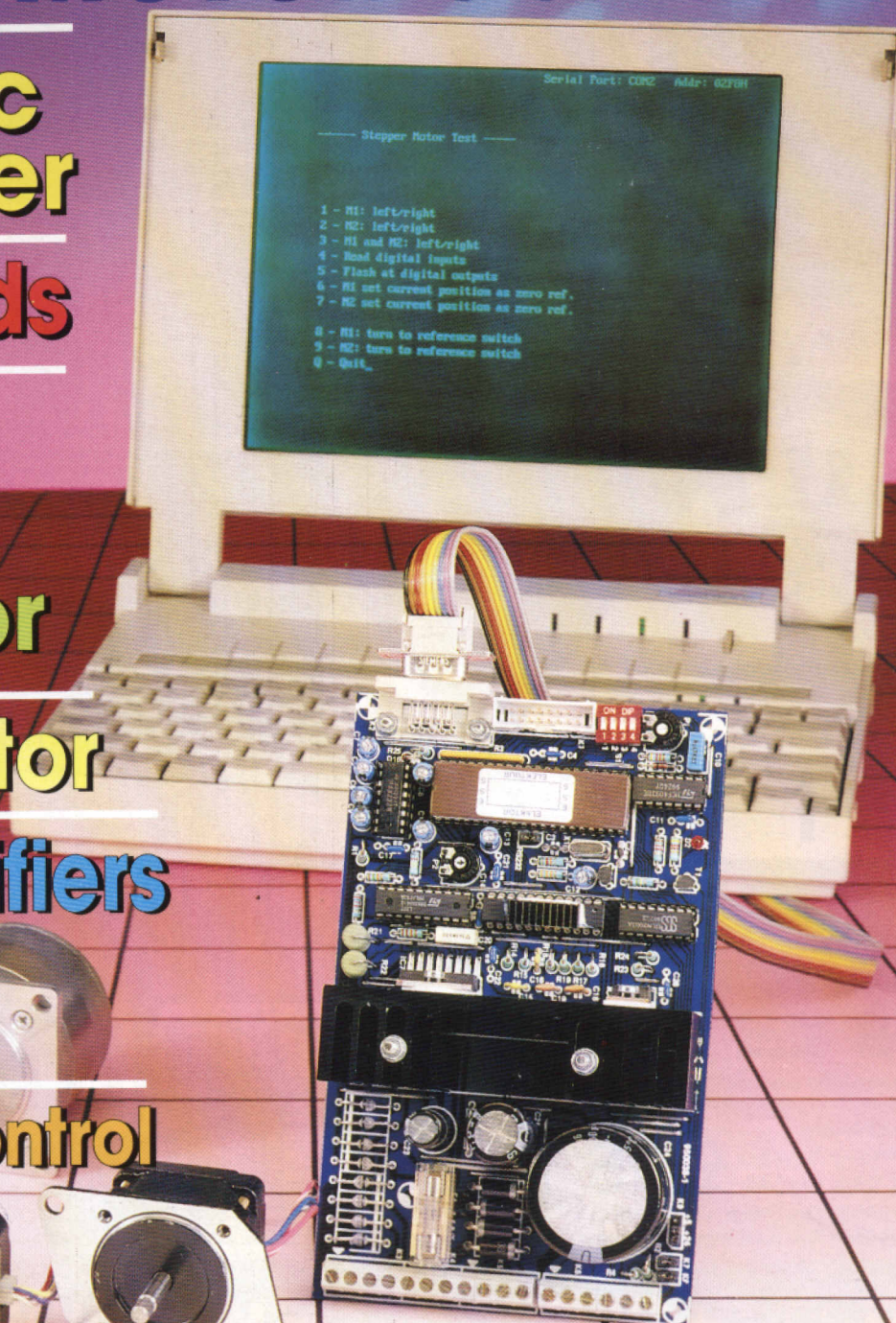
Chip cards

Simple
function
generator

Bat detector

New amplifiers
for wideband
techniques

Sun blind control



AUDIO & HI-FI • COMPUTERS & MICROPROCESSORS • DESIGN IDEAS • RADIO, TELEVISION & COMMUNICATIONS • SCIENCE & TECHNOLOGY • TEST & MEASUREMENT

In next month's issue

- **FOCUS ON:**
AUDIO STANDARDS
& TEST METHODS
- MIDI analyser
- Digital sine wave
generator
- NiCd battery-quality tester
- Rechargeable alkaline
batteries
- 89C51 programmer
- ADR-Astra digital radio
- and others for your
continued interest.

Front cover

Many computer owners use their computer to control electromechanical systems. In such applications, it is often required to switch and control stepper motors. The circuit presented on page 36 communicates with the PC via the serial interface, and is capable of driving two stepper motors. One of these takes whole or half steps, the other half steps only. The control board is a general-purpose design that is suitable for a wide range of applications involving stepper motors.

Copyright © 1995 Elektor

A B C
AUDIT BUREAU OF CIRCULATIONS

CONSUMER PRESS

APPLICATION NOTE

- 54** New amplifiers simplify wideband techniques
A Maxim Integrated Products Application

COMPUTERS & MICROPROCESSORS

- 20** **FOCUS ON:** Microcontroller development systems
By our editorial staff

GENERAL INTEREST

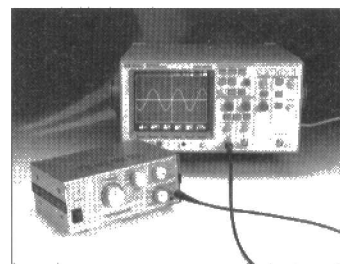
- 14** **CHIP CARDS:** an introduction
Based on an article by J. Heine
- 30** **COURSE:** The digital solution
Part 5: Storing data
By Owen Bishop
- 36** **PROJECT:** Stepper motor control
Design by B. Yahya
- 48** **PROJECT:** Electronic barometer
Design by J. Ruiters
- 62** **PROJECT:** Bat detector
Design by L. Lemmens
- 76** **PROJECT:** Sun blind control
Design by A. Gessler

TEST & MEASUREMENTS

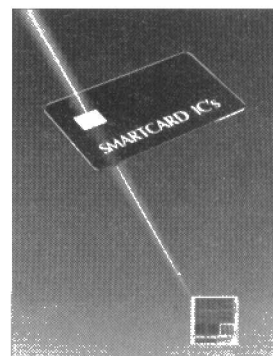
- 8** **PROJECT:** Function generator
Design by H. Bonekamp

MISCELLANEOUS INFORMATION

- 81** Book availability & prices
- 82** Buyers' guide
- 80** Corrections to earlier articles
- 5** From the World of Electronics
- 82** Index of advertisers
- 70** Readers' services
- 7** RS Components International goes CD-ROM, too
- 81** Switchboard
- 72** Terms of Business



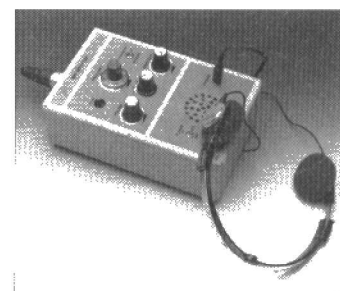
Function generator - p. 8



Chip cards - p. 14



Focus on microcontroller systems
p. 20



Bat detector - p. 62

Elektor Electronics is published monthly, except in August, by Elektor Electronics (Publishing), P.O. Box 1414, Dorchester, Dorset DT2 8YH, England. The magazine is available from newsagents, bookshops, and electronics retail outlets, or on subscription at an annual (1994/95) post paid price of £28.00 in the United Kingdom; air speeded: £35.00 in Europe, £44.00 in Africa, the Middle East and South America; £46.00 in Australia, New Zealand and the Far East; and \$US 59.00 in the USA and Canada. Second Class Postage paid at Rahway N.J. Postmaster: please send address corrections to Elektor Electronics, c/o Mercury Airfreight International Inc., 2323 Randolph Avenue, Avenel, New Jersey, N.J. 07001.

From the World of Electronics

Consultative expertise - by satellite

The development of the CAMNET telepresence system by British Telecom Laboratories (BTL) is about to revolutionize many of our ideas and practices concerning remedial aid at a distance. The term remedial aid is used in its widest sense to include not only medical treatment and operations but trouble shooting, emergency repairs and specialized maintenance in a variety of systems, equipment and situations: in fact, in all situations where the man on the spot needs immediate and expert advice to tackle and complete successfully the task in hand.

CAMNET makes this possible. It is a communications system that uses a headset incorporating a miniature camera and a built-in screen. Transmissions from the headset can be sent via an umbilical, or radio, or optical link to an integrated services digital network (ISDN) and thence to the remote expert who can send back verbal instructions and visual data in the form of diagrams, text or pointers which can be viewed on the screen. But this system is feasible only where there is an ISDN channel readily available, while expertise is often needed in remote parts of the world where no such facilities exist.

This matter has now been rectified in a joint enterprise by BTL and ABB Nera (an ASEA Brown Boveri company) to develop a system in which CAMNET telepresence can be provided by satellite in any part of the world, however remote.

CAMNET is an acronym used by BTL for camera and network technology. At the heart of the system is an audio visual headset based on a pilot's standard headset comprising earphones and noise-cancelling microphone; but one earphone has been removed so that the wearer can hear and respond to local audio stimuli. Attached to the left side of the headset above the ear cup is a small CCD camera, which in conjunction with a codec can send a compressed video picture of the scene being viewed via the Inmarsat A high-speed data facility and the ISDN network to the expert.

Private eye

The headset has a miniature screen, which enjoys the soubriquet of Private Eye, viewed with one eye at a distance of a few centimetres. The optics of Private Eye gives the viewer the observed effect of a 300-mm monitor at a distance of one metre. The image is an intense monochrome red-on-black, high-resolution dot matrix with a contrast ratio of 70:1, making it ideal for use in bright conditions. The pixel resolution is 720×280 (H×V), suitable for viewing highly detailed line drawings. The image is produced by an LED bar of 280

elements which is modulated at up to 8 MHz, the image being swept across the user's field of view by a resonating mirror at 50 Hz.

The electronics necessary to drive the CCD camera and Private Eye are housed in a belt-pack connected to the SatCom terminal by a 30-m umbilical; this will be replaced presently by a cordless link.

The expert at the base end of the satellite link uses a PC terminal connected to a BT video codec and the ISDN network. On its video display, he will view the image transmitted from the CCD camera on the CAMNET headset. The PC would also contain data for the expert to send to the headset wearer in the field such as line diagrams, circuit diagrams, or text.

The information is converted to the correct format for display on Private Eye by proprietary software running under Windows, and transmitted at the press of a button: it is sent via the ISDN and SatCom in a dedicated area of the 64-kbit s⁻¹ channel separate from the audio and video.

Intrinsically robust

The Saturn Compact Inmarsat earth station is intrinsically robust and designed for trouble-free operation. A recent member of the family of ABB Nera Saturn Inmarsat earth stations, with over 3300 in operation around the world, it has a new design and incorporates state-of-the-art components to save weight, space and improve performance.

In addition to the telepresence equipment, it can be supplied with a variety of communications devices such as teleprinters, facsimile transceivers, data modems, and various types of power supply. For the telepresence application, as well as teleconferencing, it works in conjunction with a 64-kbit s⁻¹ duplex high-speed data (HSD) system which digitizes and compresses video material before transmission.

Three units

The hardware for the complete system comprises three units, each shock-mounted and housed in a 700×600×300 mm ruggedized moulded polythene trunk. Two trunks weigh 34 kg each, the third 15 kg. The trunks, which are weatherproof, are easily portable by light transport and can be manhandled to the most difficult sites.

The trunk for the earth station terminal contains all the requisite electronics as well as a sectionalized parabolic dish which can be quickly assembled on site bringing the terminal on the air within five minutes. The complete telepresence system should take no more than ten minutes to become completely operational.

The applications envisaged for the satellite system include any activity where it has been necessary in the past to fly an expert to the scene, engendering not only

considerable cost, but a substantial time delay—first in getting the expert there, and then in getting the items of equipment he has diagnosed necessary to rectify the problem. The potential applications are only too obvious for all types of complex and specialised equipment in service around the world. Those relating to oil platforms, ships and aircraft spring immediately to mind.

Optoelectronics communications research keeps Britain ahead

Two researchers at British Telecom Laboratories, Kevin Smith and Julian Lucek, have developed in recent months what may be the first all-optical signal regenerator, a significant advance that enhances and reinforces Britain's leading position in optical communications. The BT team is examining ultra-fast data processing for the sophisticated optical-fibre networks needed to meet the world's telecommunications demands of the next century.

Their achievement uses the results of research over the past six years at the Optoelectronic Research Centre (ORC) at Southampton University. Here, 100 scientists and support staff in world-class research laboratories sustain and advance previous pioneering work by promoting the theory, basic science and technology of optoelectronics.

Communications achievements

As a prestigious body, ORC maintains strong links with industry and research institutions around the world, and works to increase the numbers of broadly-based and highly-trained scientists and engineers in its field. With its established grant of £ 12 million over six years, ORC is creating new applications for a world market that has grown to more than £ 7 billion a year in less than 20 years. The Southampton initiative has been rewarded by the BT scientists' most recent development and by communications achievements in other British companies such as STC, Mercury and Cable & Wireless.

Britain is among the front-runners striving towards the concept of a vast information network straddling the earth and providing instantaneous access to centres of knowledge, information and entertainment. This is the Holy Grail of modern telecommunications, a prize sought after by the advanced economies. Mankind's big leap forward lies in communications.

Optical amplifier

The optical amplifier, the erbium-doped fibre,

invented at Southampton in 1987, is revolutionizing optical communications around the world. This device is considered one of the last decade's top three inventions in all fields and is recognized worldwide as a British discovery. The trans-Pacific link between the US and Japan, to be inaugurated this year, will use erbium-doped fibre amplifiers.

Britain's STC Submarine Systems is a lead company in undersea and trans-oceanic communications and supplies a large part of the world market. This Northern Telecom business unit has won a contract for a system from Spain to Britain, Belgium and the Netherlands. From Spain to the UK and Belgium, the system is optically amplified, but the 284 km between Belgium and the Netherlands is an unrepeatable system thought to be the longest in the world.

Data transmission

The BT innovation could remove the need for electronic amplifiers and make a significant contribution to optical sub-oceanic links, enabling a variety and profusion of information to reach faraway destinations accurately and reliably. Only mode-locked fibre lasers in ultra-fast pulses will be able to accommodate the enormous data transmission demands created by the homes and businesses of the 21st century. This steps beyond the traditional notion of a simple pulse source and the laser is performing essential network functions at the heart of all-optical processors.

The BT research team, although capable of generating unimaginably fast pulses in the femto-second (10^{-15} s) range, prefers to concentrate on a 'more realistic' time-scale of 100 Gbit s^{-1} .

According to Kevin Smith: "To achieve networks with almost unlimited range at these speeds and beyond, we must use all-optical techniques and employ light itself to control light, or photons to control photons. Optical technology is fundamentally faster than the alternative – electronics – where electrons ultimately control the photons and vice versa."

Colossal potential

Most of the BT work covers the infrared spectral region and uses light of 1.3 μm and 1.55 μm wavelength. The time-scales are infinitesimally small, the distances large, but their potential is colossal. The reliability of the system is excellent and, compared with the conventional electronic amplifier, the optical system is far simpler. For the same return, an electronic system requires signal detection, conversion, processing and optical remodulation.

Kevin Smith's development uses erbium amplifiers, mode-locked fibre lasers and, to support this telecommunications technology of the 21st century, a wave phenomenon known as the soliton, brought to optical reality by ORC in recent years.

A soliton is a non-dispersive optical pulse, a pulse that in principle does not broaden. Lasers, unlike normal pulses, can create soliton-like phenomena. Only in the last few years have scientists both in Britain and elsewhere begun to see the soliton as a fundamental of future communications technology, providing a near-perfect, dispersion-less pulse that maintains its fidelity while in the transmission system.

Erbium fibre

BT has been pioneering the use of fibre lasers

in generating these pulses, but pulses transmitted over thousands of kilometres would suffer significant loss if they were not rescued by erbium-fibre amplifiers. The core of this fibre is doped with ions of the rare metal erbium; a laser pump source is used to excite them. A signal weakened by distance along a fibre can extract this energy and receive gain from the excited erbium. The amplifiers, installed up to 50 km apart, ensure the entire network is transparent and eliminate huge losses.

This development is revolutionizing the way engineers are starting to think of these networks, allowing them to concentrate on the data bits, that is, pulses used to communicate information, and this is where the solitons come in.

Fibre lasers generate the pulses, their sources being the same as the amplifiers inserted along the system. The use of mode-locked fibre lasers represents one layer of technology beyond the fibre laser. This is a very rapidly evolving field, where many are competing for the pulse source prize. In the laboratory, at the moment, the mode-locked erbium fibre laser is favourite.

The capacity of soliton systems is very high and in this 'shrunk-time' world, where a second is measured in hours, today's electronics can not easily manipulate the pulses. All-optical processing, with switching capabilities of the order of picoseconds ($=10^{-12}$ s), reigns supreme, at least for the time being.

Produced and published by **ELEKTOR ELECTRONICS (Publishing)**

Editor: Len Seymour
Technical Editor: Jan Buiting

Editorial & Administrative Offices:
P.O. Box 1414
DORCHESTER DT2 8YH
England

Telephone: (01305) 250 995 (National)
or +44 1305 250 995 (International)
Fax: (01305) 250 996 (National)
or +44 1305 250 996 (International)

U.K. Advertising Office:
3 Crescent Terrace
CHELTENHAM GL50 3PE
Telephone: (01242) 510 760
Fax: (01242) 226 626

International Advertising Office:
Elektur BV
P.O. Box 75
6190 AB BEEK
The Netherlands
Telephone: +31 46 38 94 44
Fax: +31 46 37 01 61

Subscriptions:
World Wide Subscription Service Ltd.

Unit 4, Gibbs Reed Farm
Pashley Road
TICEHURST TN5 7HE
Telephone: (01580) 200 657 (National)
or +44 1580 200 657 (International)
Fax: (01580) 200 616 (National)
or +44 1580 200 616 (International)

Head Office:
P.O. Box 75
6190 AB BEEK
The Netherlands
Telephone: +31 46 38 94 44
Telex: 56617 (elekt nl)
Fax: +31 46 37 01 61
Managing Director:

Johan H. Boermann

Deputy Managing Director:
Manno M.J. Landman

Editor-in-Chief/Publisher:
Pierre E.L. Kersemakers
Commercial Manager:
Karel van Noordenne

Distribution:
SEYMOUR
1270 London Road
LONDON SW16 4DH

Printed in the Netherlands by NDB.
Zoeterwoude

Overseas editions:

FRANCE
Elektor sarl
Les Trois Tilleuls
B.P. 59: 59850 NIEPPE
Editor: G.C.P. Raedersdorf

GERMANY
Elektor Verlag GmbH
Süsterfeld Straße 25
5100 AACHEN
Editor: E.J.A. Krempelsauer

GREECE
Elektor EPE
Karaiskaki 14
16673 Voula—ATHENA
Editor: E. Xanthoulis

INDIA
Elektor Electronics PVT Ltd
Chhotani Building
52C, Proctor Road, Grant Road (E)
BOMBAY 400 007
Editor: C.R. Chandarana

ISRAEL
Elektoreal
P.O. Box 41096
TEL AVIV 61410
Publisher: M. Avraham

NETHERLANDS

Elektuur BV
Peter Treckpoelstraat 2-4
6191 VK BEEK
Editor: P.H.M. Baggen

POLAND

Elektor Elektronik
02-777 Warszawa 130
Skrytka Pocztowa 271
Editor: W. Marciniak

PORTUGAL

Ferreira & Bento Lda.
R.D. Estefani, 32-1°
1000 LISBOA
Editor: F. Ferreira de Almeida

SPAIN

Resistor Electronica Aplicada SA
P. de la Castellana, 212-4° Izda
28046 MADRID
Editor: Agustin Gonzales Buelta

SWEDEN

Electronic Press AB
Box 5505
14105 HUDDINGE
Editor: Bill Cedrum

RS COMPONENTS INTERNATIONAL GOES CD-ROM, TOO

Preliminary details of the first release of the RS International catalogue on CD-ROM were unveiled at a press briefing at the RS headquarters in Corby, on 18 January 1995. This CD-ROM, which will be available in March 1995, follows the resounding success of the UK version which was first introduced in July 1994.

Designed to assist equipment designers, engineers and purchasers in the selection and ordering of electronic, electrical and mechanical components, RS Components International has developed a CD-ROM version of its product catalogue. The RS 'Electronic Catalogue' runs on all standard IBM compatible PC configurations.

The first of its kind and available free to RS customers, the Electronic Catalogue, like its paper companion, is updated annually. With over six Gigabytes of compressed data on a single CD-ROM disc, detailing over 40,000 components, and including the RS Technical Data Library, the user has a range of options that help speed up selection of the product best suited to an application.

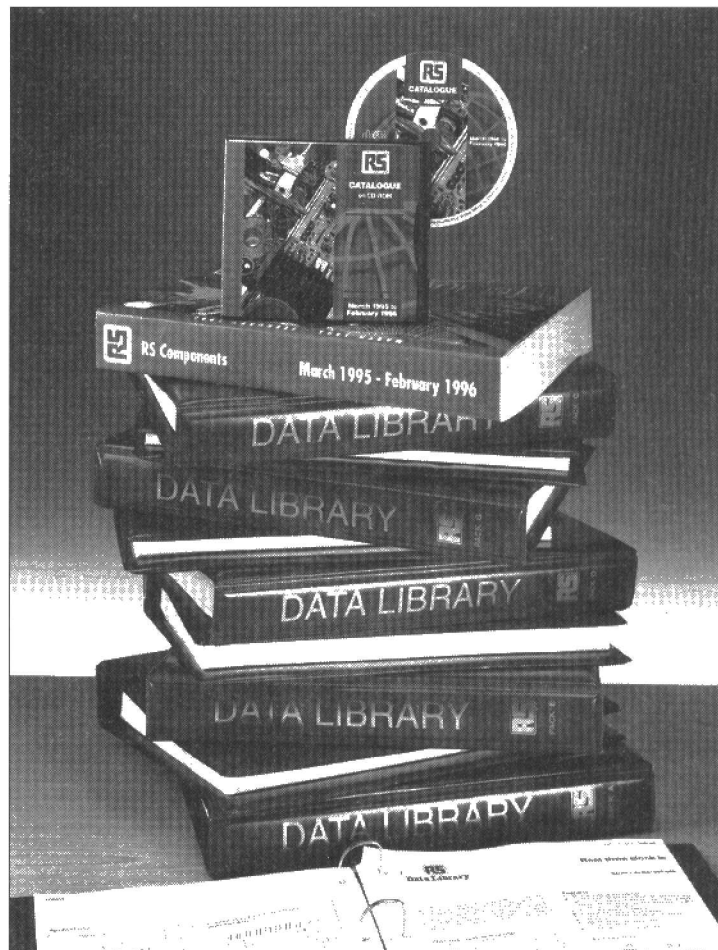
Searching by product type, the user can 'browse'

as with the conventional catalogue, moving progressively between section, sub-section and product group before making a final product selection. Alternatively, the user can search by typing in a key word, or a partial or complete version of the RS stock number or manufacturer's own part number.

Containing approximately 10,000 full colour product illustrations, the CD-ROM offers a unique 'virtual page' function that brings up images of a range of alternative products for browsing, while a 'view' function examines a particular product in detail, displaying all relevant catalogue data. A 'related product' function allows the user to identify products used in conjunction with the product choice.

The ordering function of the electronic catalogue enables significant time savings to be made. In making a product selection, a standard order form can be called to simultaneously record order details of the selected item. Order forms can be archived and output to printer or fax using an appropriate software/hardware interface.

RS Technical Datasheets form an integral part of the new electronic catalogue. During the product selection



The complete RS Components catalogue (who does not have a copy?) and RS Data Library are now available on CD-ROM. Note that the international version of the catalogue consists of one (very thick!) book only, whereas the UK version is split into three volumes.

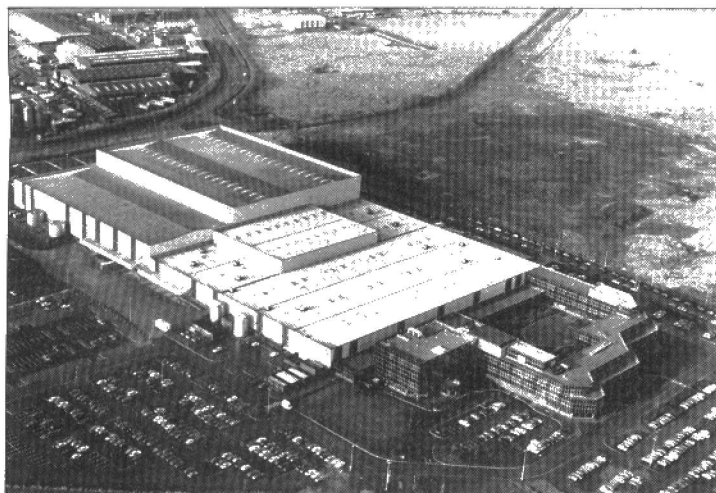
process, supporting in-depth technical datasheets can be called up for reference, making it even easier to identify the most appropriate solution to a technical problem.

A simple start-up procedure ensures fast installation of the electronic catalogue, while a powerful graphic tutorial section and on-line help facility help to guide the user around the new system. The CD-ROM runs on a conventional CD-ROM reader operating with a standard PC equipped with a minimum of a 386 processor, 4 MB RAM, Windows software and VGA screen. For enhanced operation, a 486-based system with an SVGA, 256-colour screen is recommended.

The international versions of the CD-ROM catalogue will be available from March

1995 in Europe and the rest of the world, with country-specific introductory sections ensuring customers receive distribution and contact information relevant to their market. (950059)

Further information from your local/national RS Components distributor, or from RS Components International, P.O. Box 99, Corby, Northants NN17 9RS, United Kingdom. Tel. (+44) 1536 201234, fax (+44) 1536 401096. Telex: 342512.

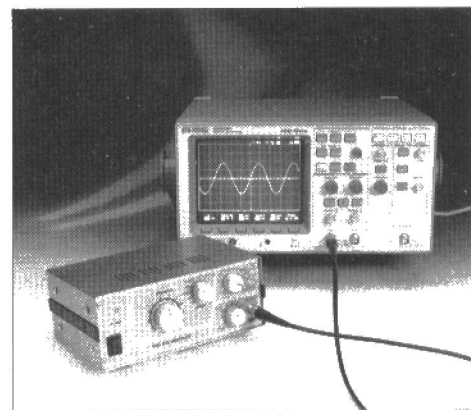


The RS Components headquarters are housed in a 75,000 m² (equivalent in size to ten football pitches) warehouse and office complex in Corby, Northants, England. Over 10,000 orders are processed at terrific speed every day at this location, including orders for the 'retail' branch of RS Components, Electromail.

FUNCTION GENERATOR

Design by H. Bonekamp

A simple function generator is described, which provides rectangular, triangular and sinusoidal waveforms in the frequency range d.c.–100 kHz. In contrast to many 'simple' function generators, it provides a fairly good sine wave.



Almost all function generators consist of a variable-frequency, rectangular-wave oscillator that provides a number of switch-selected frequency ranges. Its output is applied to an integrator which converts the rectangular waves into triangular ones. Finally, the triangular waves are converted to 'sine waves' by soft clipping with a diode.

The present generator is no exception as is shown in **Fig. 1**. The triangular-to-sine wave converter is based on diodes and has an output voltage of $5U_D$, where U_D is the forward voltage of one diode. It can be shown that for correct operation, the converter needs an input of $(\pi/2) \times 5U_D$.

Moreover, the diodes in the converter make it necessary for the input voltage to be temperature-compensated. This is assured by limiting the output of the comparator to $1U_D$ by two anti-parallel connected diodes. This is raised to a level of $5U_D$ by the amplifier.

The 1:0.5 π ratio of the feedback resistors ensures that the input voltage to the triangular-to-sine wave converter is $(\pi/2) \times 5U_D$ as required.

Circuit description

In **Fig. 3**, the comparator of **Fig. 1** is formed by IC_{1b} . Capacitor C_2 , shunting R_2 , compensates for the delays caused by op amps IC_{1a} and IC_{1b} , so that the level of the output voltage of the rectangular-wave generator remains fairly constant up to 100 kHz.

Capacitor C_1 decouples R_1 for h.f. to prevent the input capacitance of IC_{1b} having an adverse effect on the wave shape.

Resistor R_1 compensates for the offset error caused by the bias current through R_2 – R_3 .

The limiter consists of anti-parallel connected diodes D_1 and D_2 . These are fast types to ensure that the circuit quickly operates correctly. Since the limiter should operate symmetrically, it is important that the diodes are matched.

The amplifier is formed by IC_{1a} . This is an op amp with a fairly high slew rate (300 V μ s⁻¹) which is essential for a well-shaped voltage at frequencies up

to 100 kHz. Its amplification is arranged at exactly $\times 5$ by R_5 and R_6 .

Frequency control of the oscillator is obtained by driving an integrator, consisting of R_8 , IC_{2b} and one of capacitors C_3 – C_7 , with the rectangular wave. The op amp ensures that the capacitor selected with S_{1a} is charged or discharged at constant current. This gives rise to a triangular voltage. The speed at which charging and discharging takes place depends on the capacitance and the applied voltage. The value of each of capacitors C_3 – C_7 differs by a factor 10 from the preceding one. Switch S_1 , which selects one of the capacitors, thus provides subdivision of the frequency range into five.

The triangular voltage is applied to the non-inverting input of IC_{1b} and determines, in conjunction with the output of the $\times 5$ amplifier, the exact change-over point of the comparator.

The triangular voltage is available at the output of IC_{2b} . Since it is important for the integrator that the bias current is as low as feasible, IC_2 is an op amp with (high-resistance) JFET inputs. The low slew rate does not matter here.

The peak value of triangular voltage is, as explained earlier, 0.5π higher than that of the rectangular wave. To ensure that these level differences do not have a deleterious effect during switching from rectangular wave to tri-

Parameters

Frequency ranges:

1 Hz – 10 Hz

10 Hz – 100 Hz

100 Hz – 1 kHz

1 kHz – 10 kHz

10 kHz – 100 kHz

Functions: rectangular, triangular, sine wave

Rise time (rectangular wave):
<100 ns

THD (sine wave): <<0.75% (at 1 kHz)

Output voltage: 0–20 V peak-to-peak

Output impedance: 600 Ω

angular wave, the output of the integrator is reduced by $2/\pi$ by R_9 .

The triangular-to-sine wave converter is not a simple diode clipper, as in many simple function generators, but consists of a JFET op amp with in its feedback loop two rows of five series-connected diodes, D_3 – D_{12} , and resistors R_{12} – R_{14} . The output of IC_{2a} is thus not clipped by one diode junction, but in three stages both on the leading and the trailing edge. This design results in a sine wave that has a nearly true-sinusoidal shape—see **Fig. 2**. Preset P_3 provides accurate offset compensation.

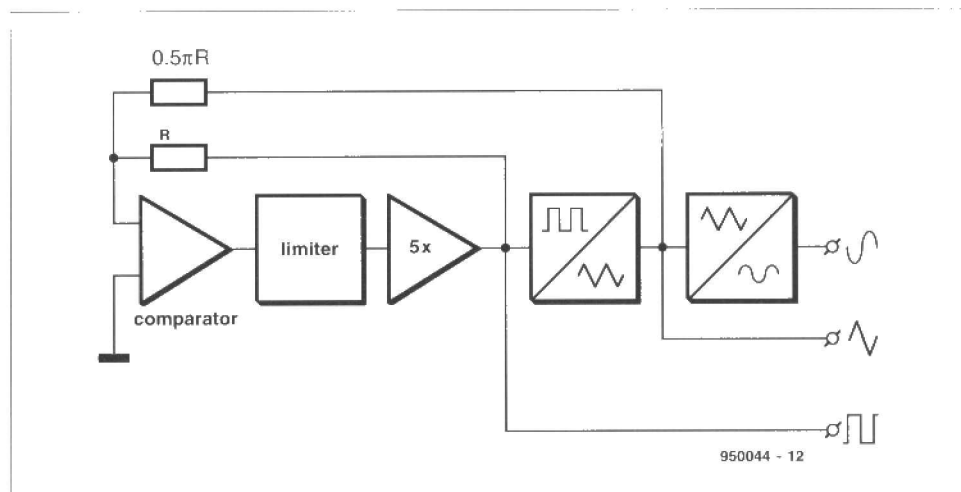


Fig. 1. Principle of a function generator.

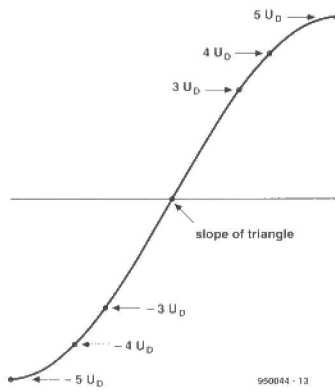


Fig. 2. How the sine wave is shaped.

The three output signals are applied to FUNCTION selector S_2 . Circuit IC_3 amplifies and buffers the selected output signal. The amplification is set to $\times 3.5$ by R_{15} and R_{16} , so that the output voltage can be adjusted with P_4 between 0 V and 20 V_{pp}. The output impedance is fixed at 600 Ω by R_{17} .

The symmetrical power supply follows the usual pattern of mains transform, bridge rectifier, buffer capacitors and two voltage regulators, IC_4 and IC_5 . Since the circuit does not draw much current, the specification of the transformers and buffer capacitors is modest.

Construction

The generator is intended to be built on the printed-circuit board shown in Fig. 4. Note that the transformer, switches and preset controls are mounted directly on to it.

It is advisable to adhere strictly to the components and devices specified in the parts list. Many resistors have a tolerance of not more than 1%. Capacitors C_3 – C_7 should be good quality types; do not use an electrolytic capacitor in the C_3 position, but a polypropylene or polyester type.

Diodes D_1 and D_2 should be matched. Instead of buying two, buy four of them. From these, select the

two whose knee voltages are identical or very nearly so. This is ascertained by connecting the diodes in series with an 8.2 k Ω resistor to a 12 V d.c. source, and measuring the drop across each diode with a digital voltmeter. Do not touch the diodes during the measurement and make sure that the ambient temperature remains constant: small differences in temperature can have a large effect on the measurement.

The same applies to the 1N4148 diodes for the triangular-to-sine wave converter. Using the method just described, select ten with an identical or near-identical knee voltage. From these, select five pairs that are identical: D_3 – D_4 ; D_5 – D_6 ... D_{11} – D_{12} .

The completed prototype board is shown in Fig. 5. This is readily fitted in an 80 \times 200 \times 132 mm enclosure—see Fig. 6—with suitable spacers. A suggested front panel (a photo copy of which can be used as a template for drilling the front panel) is shown in Fig. 7.

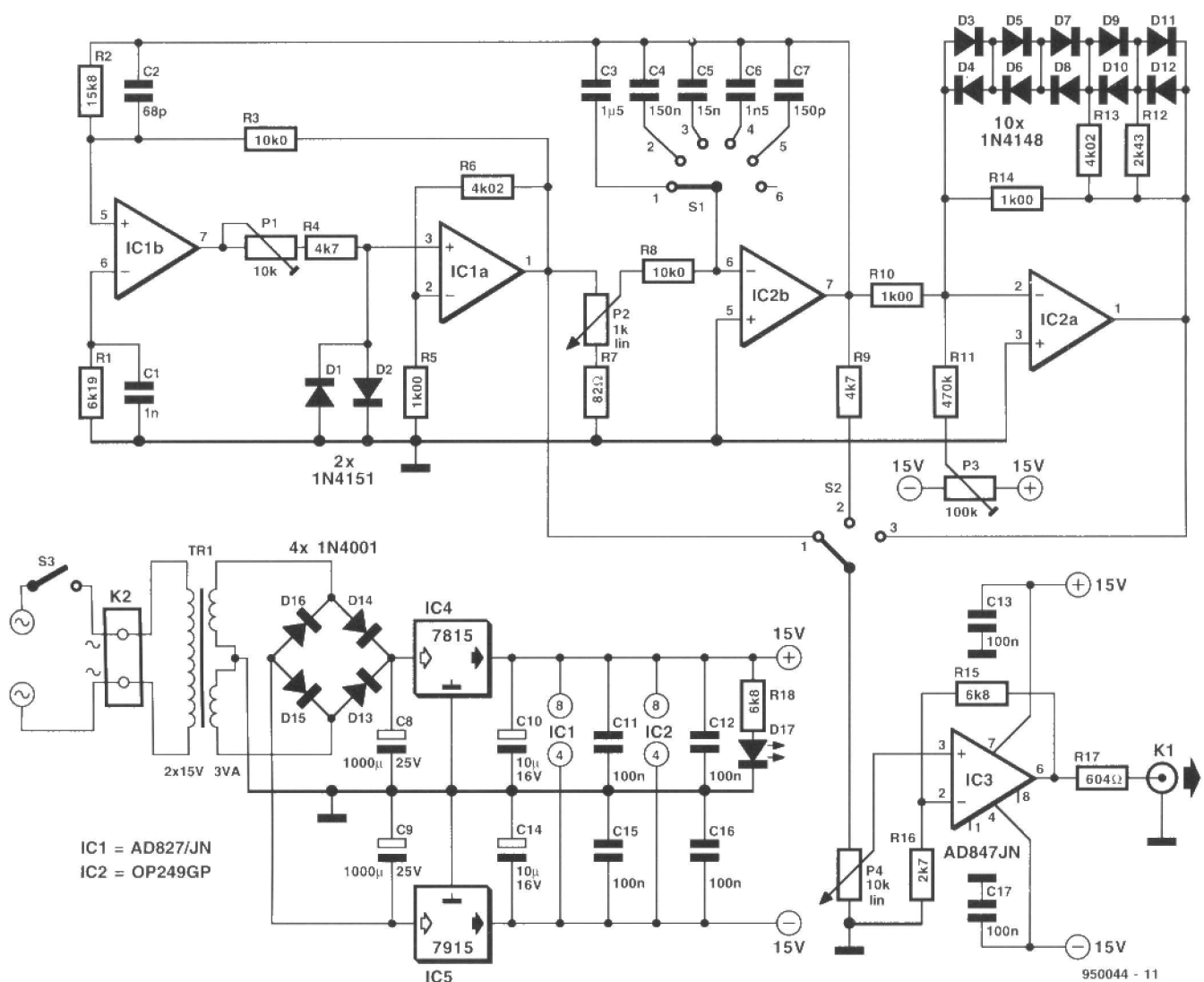


Fig. 2. Circuit diagram of the function generator.

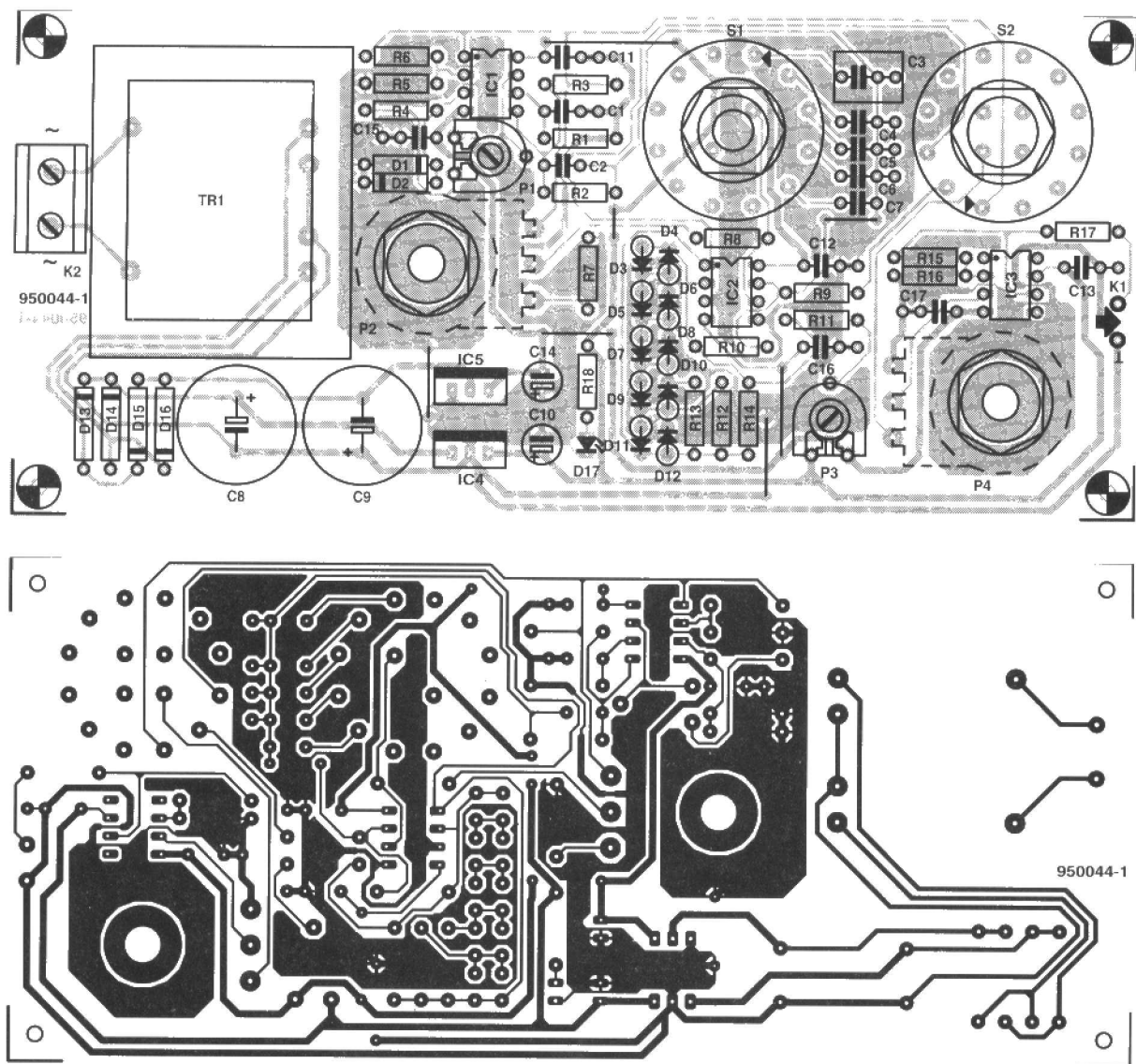


Fig. 4. Printed-circuit board for the function generator.

Calibration

There are two calibration controls: P_1 and P_3 . The former sets the operating point of the limiter, which is important for the production of the third harmonic of the sine wave; the latter causes a small offset correction voltage to be added at the input of op amp IC_{2a} , which affects the second harmonic. A spectrum analyser makes their setting easy: adjust them (at 1 kHz) for minimum amplitude of the two harmonics.

Where a spectrum analyser is not available, calibration can be carried out with a dual-channel oscilloscope and a digital voltmeter.

Apply one channel of the scope to the junction R_6 -pin 1 of IC_{1a} , and the other channel to junction R_{12} - R_{13} - R_{14} . Connect the scope's earth to junction R_7 - P_2 .

Switch on the generator and the oscilloscope and set the generator to 1 kHz, whereupon channel 1 shows the rectangular wave and channel 2 the sine wave. Adjust the attenuators and

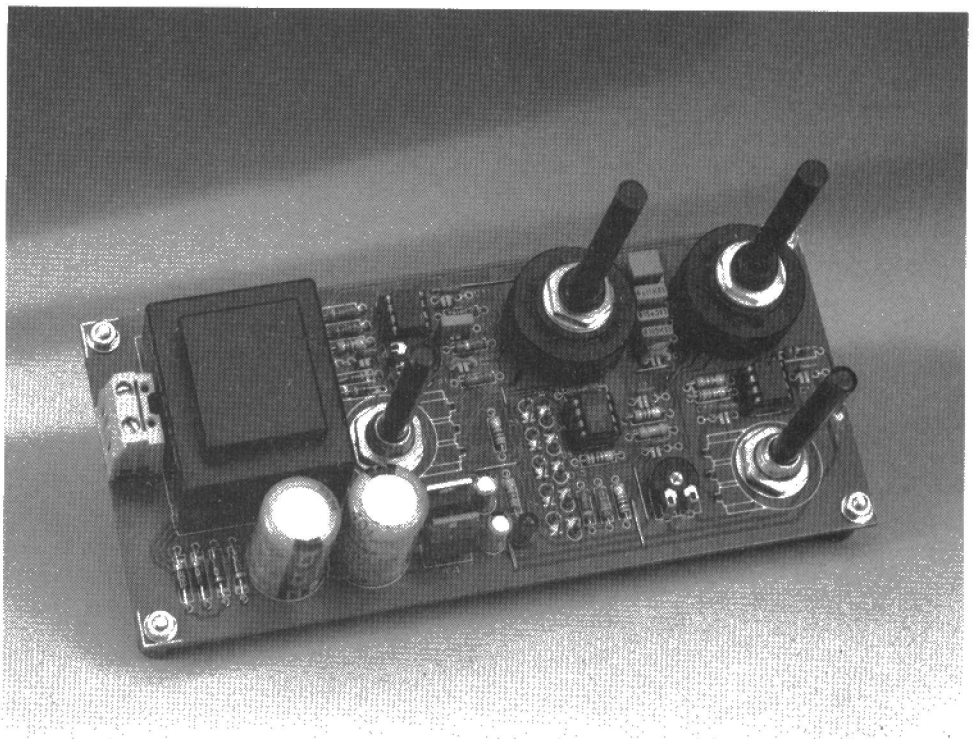


Fig. 5. Completed printed-circuit board.

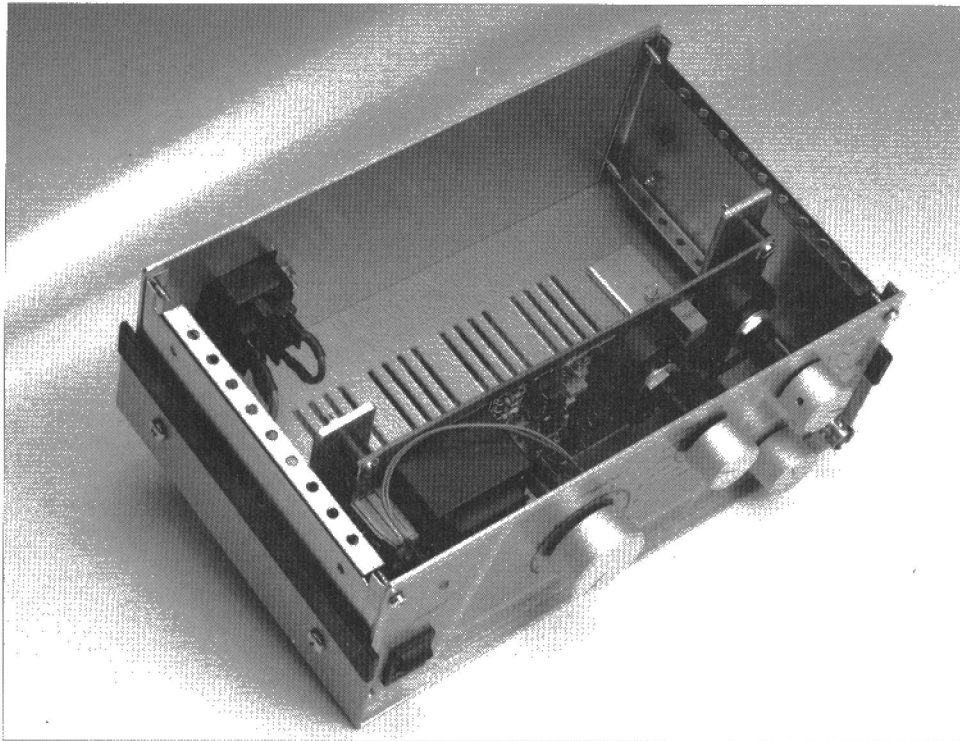


Fig. 6. Completed function generator with top cover removed.

X/Y controls of the scope so that both waves fill the screen and cover one another. Then, adjust P_1 until the amplitudes of the two waves are equal.

Set the digital voltmeter to the direct voltage range and connect it across the output of the function generator.

Turn P_4 fully anticlockwise and note the reading on the voltmeter: this is the offset voltage of IC_3 .

Turn P_4 fully clockwise and adjust P_3 until the voltmeter reading is the same as in the preceding paragraph.

Parts list

Resistors:

$R_1 = 6.19 \text{ k}\Omega$, 1%
 $R_2 = 15.8 \text{ k}\Omega$, 1%
 $R_3, R_8 = 10.0 \text{ k}\Omega$, 1%
 $R_4, R_9 = 4.7 \text{ k}\Omega$
 $R_5, R_{10}, R_{14} = 1.00 \text{ k}\Omega$, 1%
 $R_6, R_{13} = 4.02 \text{ k}\Omega$, 1%
 $R_7 = 82 \Omega$
 $R_{11} = 470 \text{ k}\Omega$
 $R_{12} = 2.43 \text{ k}\Omega$, 1%
 $R_{15}, R_{18} = 6.8 \text{ k}\Omega$
 $R_{16} = 2.7 \text{ k}\Omega$
 $R_{17} = 604 \Omega$, 1%
 $P_1 = 10 \text{ k}\Omega$, preset

$P_2 = 1 \text{ k}\Omega$, linear potentiometer
 $P_3 = 100 \text{ k}\Omega$, preset
 $P_4 = 10 \text{ k}\Omega$, linear potentiometer

Capacitors:

$C_1 = 1 \text{ nF}$, polypropylene
 $C_2 = 68 \text{ pF}$, ceramic
 $C_3 = 1.5 \mu\text{F}$, polypropylene/polyester
 $C_4 = 150 \text{ nF}$, polypropylene
 $C_5 = 15 \text{ nF}$, polypropylene
 $C_6 = 1.5 \text{ nF}$, polypropylene
 $C_7 = 150 \text{ pF}$, ceramic
 $C_8, C_9 = 1000 \mu\text{F}$, 25 V, radial
 $C_{10}, C_{14} = 10 \mu\text{F}$, 16 V, radial
 $C_{11}-C_{13}, C_{15}-C_{17} = 100 \text{ nF}$

Semiconductors:

$D_1, D_2 = 1\text{N}4151$ (matched - see text)
 $D_3-D_{12} = 1\text{N}4148$ (matched - see text)
 $D_{13}-D_{16} = 1\text{N}4001$
 $D_{17} = \text{LED}$, high efficiency

Integrated circuits:

$IC_1 = \text{AD}827/\text{JN}$ (Analog Devices)
 $IC_2 = \text{OP}249\text{GP}$ (Analog Devices)
 $IC_3 = \text{AD}847/\text{JN}$ (Analog Devices)
 $IC_4 = 7815$
 $IC_5 = 7915$

Miscellaneous:

$K_1 = \text{BNC connector}$
 $K_2 = 2\text{-way terminal block}$, pitch 7.5 mm
 $S_1 = 2\text{-pole, 6-position rotary switch}$
 $S_2 = 4\text{-pole, 3-position rotary switch}$
 $S_3 = \text{mains on/off switch}$
 $Tr_1 = \text{mains transformer, secondary } 2 \times 15 \text{ V, 3 VA (Velleman 2150038M - Maplin)}$
 Enclosure $80 \times 200 \times 132 \text{ mm}$
 $(3\frac{1}{8} \times 7\frac{7}{8} \times 5\frac{3}{16} \text{ in})$
 PCB Order no. 950044-1*
 Front panel foil Order no. 950044-F*
 * see p. 70

[950044]

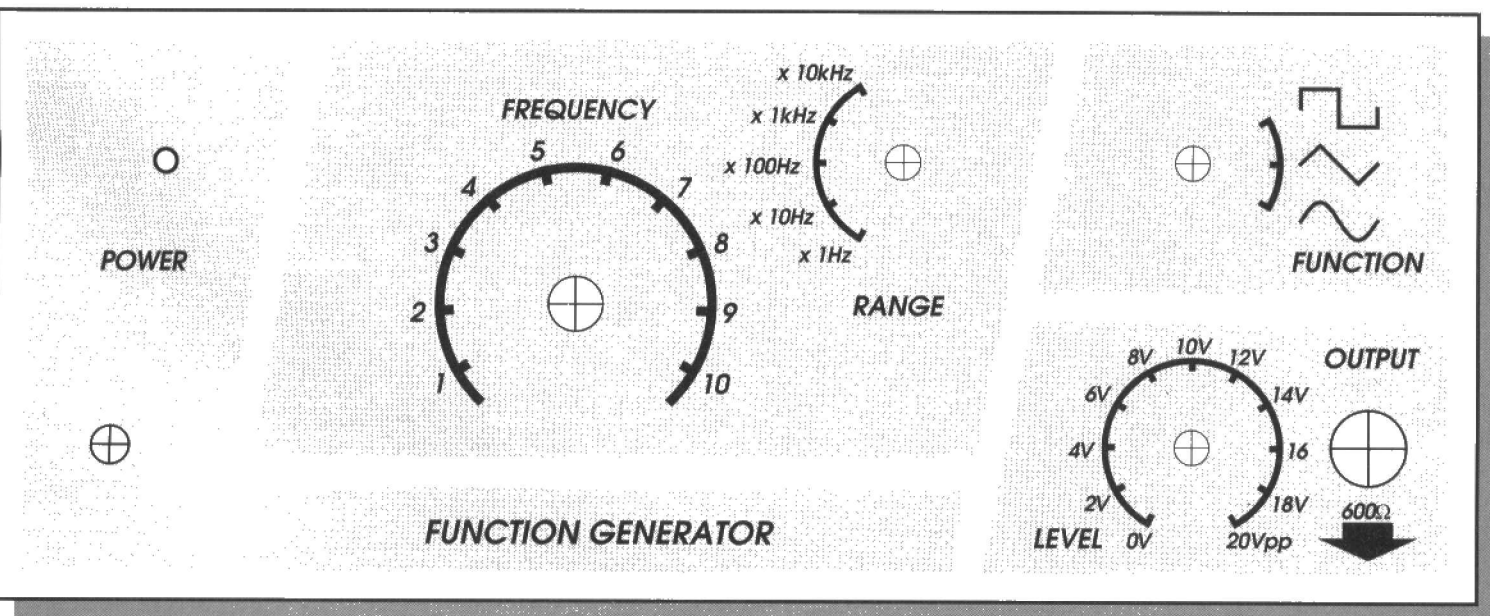
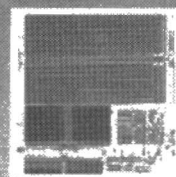
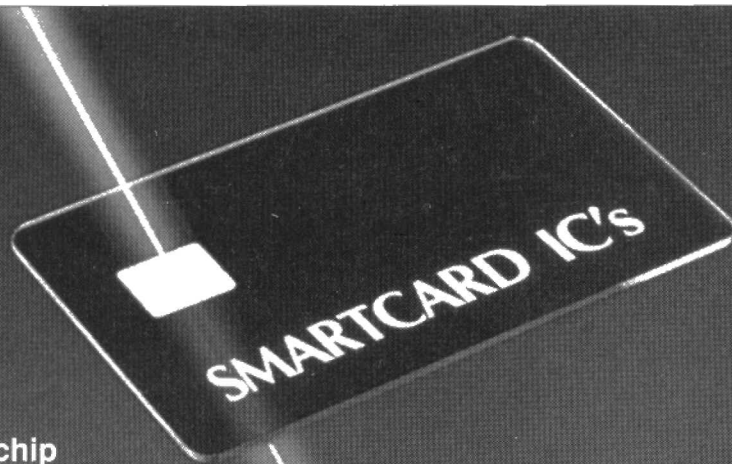


Fig. 7. Suggested front panel for the function generator (true scale).

950044-F

CHIP CARDS

The chip card is a microcontroller or memory card with a full-blown processor structure, packaged in a plastic card. Thanks to modern semiconductor integration technology, chip cards have the same size as credit cards, and are not thicker than any magnet strip card. This article is intended as an introduction to chip card technology.



Based on an article by J. Heine

CHIP cards with a variety of appearances and functions have been around since the middle of the nineteen seventies. Today, they are used increasingly in, for instance, telephone booths (though not yet in the UK) and personnel identification and work time logging systems in large plants and office buildings. In some cases, they are also used for electronic financial transactions. In the near future, further measures towards application-independent, international, standardization of the chip card is sure to give a tremendous boost to the number of applications. This will be helped by much reduced productions cost, which goes hand in hand with high production volumes. Also, a combined chipcard/magnet strip card will soon be unveiled.

The primary function of a chip card is to help identify the rightful owner, or, with non-personalized cards, to grant the user a certain service for which a remuneration is due that is within the limits of the 'value' of the card.

In this respect, chip cards are the successors of the widespread 'flexible friend', the magnet strip card issued by banks and credit card organizations. The requirements as regards physical and electrical characteristics of the chip card are laid down in ISO standard 7816, part 3.

Construction of a chip card

The generic name 'chip card' is used to cover the following products:

- Smart Card
- Memory Card
- Processor Card
- Intelligent Card
- IC card

These different names already hint at differences as regards function and inter-

nal construction. According to the ISO 7816 standard, the name 'IC Card' should be used to denote all members of the chip card family.

Magnet strip cards with their passive function and small memory capacity (342 bytes) are easily read, copied and forged. By contrast, chip cards, by virtue of their much larger memory capacity (up to 32 KByte), built-in intelligence and access lock, offer a much higher degree of safety against unauthorized use. Yet, they are relatively cheap to produce.

Production

The chip card has the same size as a bank or credit card: 85.6×54×0.76 mm. For mobile telephones and other applications where space is restricted, so-called 'Plug-in SIM[®]' cards are available with a size of 18×28×0.76 mm. The chip proper has a size of 10×10 mm², and is embedded in plastic carrier material. Because of the flexibility of the card and other external factors, the carrier 'floats' inside a clearance in the plastic carrier. The chip carrier element is produced by covering both sides of a foil with copper foil. Next, the contacts and the layout are etched (Fig. 1), and subsequently through-contacted. Onto this composite foil, an equalizing foil is laminated, from which the clearances for the chip contacts are punched. The chip is secured on to the equalizing foil with the aid of silicon rubber cement, connected to the conducting foil, and subsequently covered by another foil. The rear side of the conducting foil contains the contacts (shown in the form of a punch-out pin feed strip in the background of Fig. 1), which later form the contacts to the outside world. A further layer of foil, which has clearances of the size of the contact elements, is secured at the contact element side of the conducting foil. The finished carrier element is punched out of a larger sheet, and inserted into the card, which consists of several layers of PVC foil. These make the card resistant against high temperatures, high humidity, and chemicals. However, direct heat transfer to the card, as well as electrical noise at the chip contacts (ESD) and excessive strain caused by bending, should be avoided.

Block diagram

The basic elements in a chip card are shown in Fig. 2. They include:

- a microcontroller (CPU)
- a scratch memory (RAM)
- a program memory (ROM)
- a data memory (EPROM or EEPROM)
- an input/output block (I/O)

Depending on the application, memory cards may be preferred over processor cards. In the long term, however, the trend will be towards combination cards

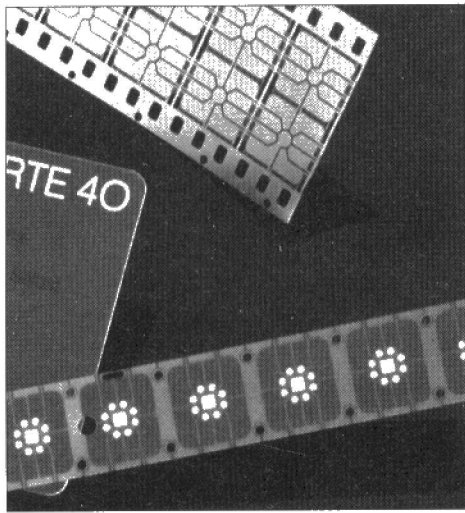


Fig. 1. Building blocks of a chip card: in front, the etched chip carrier element, in the centre, the (unfinished) card, and in the background, the punching tape.

and standardized readers which accept all types of card. Two of the world's major credit card organizations, VISA and Eurocard, already supply combination cards which allow users to make credit card purchases in the usual way using the magnetic strip system, as well as make telephone calls with automatic payment via their account. In response to this trend, telephone booths in many countries are rapidly upgraded to accept these cards.

Because of the standardized protocol as regards access, and because their 'intelligence' allows them to be tailored to future protocols, processor-type chip cards are generally considered the best candidates to pioneer a universally usable and global chip card technology.

Access

The card has six to eight gold-plated contacts with an effective contact area of

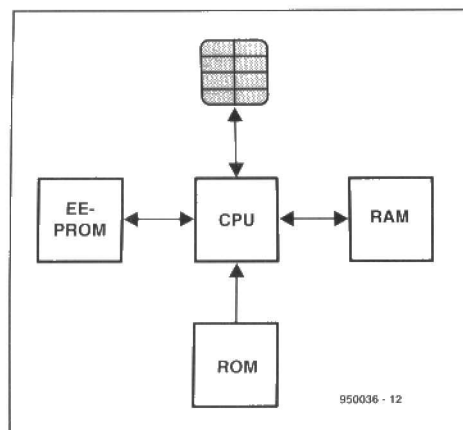


Fig. 2. The basic architecture of a chip card is fully equivalent to that of a microcontroller system.

1.7×2 mm². The two possible positions of the contacts on the card are accurately defined. The position used depends on that of the magnet strip and the printed area.

Chip card readers (also called card terminals) are currently available in a number of versions, from simple ones with spring-operated pin contacts, to zero-insertion force types with end switches. The ultimate, however, is the motor hybrid card reader which automatically moves cards into the contact position, and ejects them after reading. Figure 7 shows a simple and therefore reasonably priced card reader unit with pin contacts and an end switch (which turns the reader on and off).

The position of the contact area of a telephone card with a fixed number of 'credit units' (i.e., cost pulses) is shown in Fig. 3. The telephone card is powered by a supply voltage of 5 V (Table 1) via contacts C1 and C5 (GND), and has an on-card voltage step-up converter for the EEPROM programming voltage. A clock signal (CLK) is applied to the card via contact C3 to enable serial data to be conveyed bidirectionally via contact C7 (I/O). Contact C6 is rarely used in modern card readers. It supplies an external programming voltage (V_{pp}), which is applied after the card has been identified. Only a few types of (by now obsolete) cards require this programming voltage.

Although the functions of contacts C4 and C8 are 'reserved' according to the standard, they are not used on most cards. Contact C2 functions as a reset input which allows the 'intelligent' contact with the card to be established, followed by an identification operation

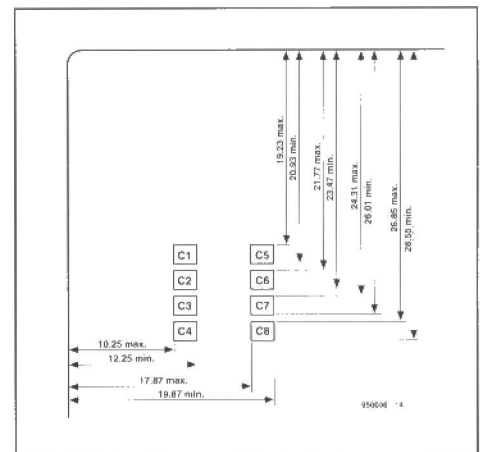


Fig. 3. Location of the eight-way contact area on the card.

contact	designation	contact	designation
C1	VCC (Supply Voltage)	C5	GND (Ground)
C2	RST (Reset)	C6	VPP (Programming Voltage)
C3	CLK (Clock Signal)	C7	I/O (Input/Output)
C4	Reserved	C8	Reserved

950036 - 16

Table 1. Functions of the electrical contacts on the chip card.

(both according to a protocol described further on).

Programming

Table 2 lists a number of the largest and best known manufacturers of chip cards. Philips and OKI concentrate on processor cores for which extensive development systems are available, and complete these cores with arithmetic processors capable of processing secu-

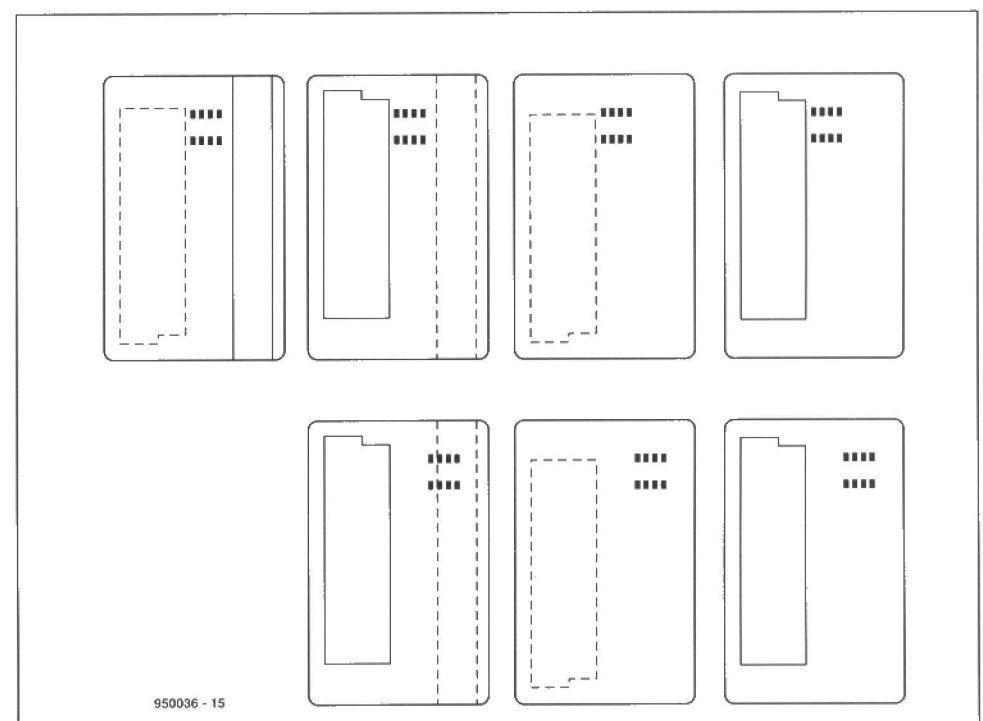


Fig. 4. Possible locations of electrical contacts and magnet strips on combination cards.

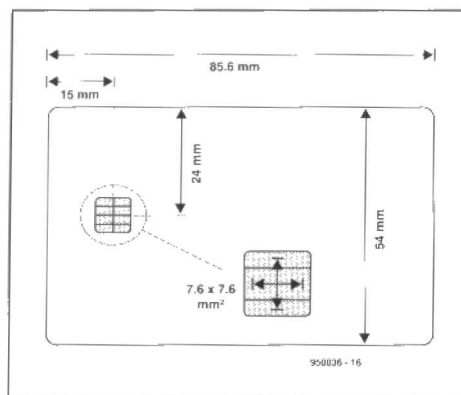


Fig. 5. Dimensions of a disposable phonecard with a fixed equivalent value.

city-sensitive data using encryption algorithms like DES (data encryption standard).

Chip cards have astoundingly large memory areas. Today, there is nothing special about 32 Kbytes of EEPROM, 32 Kbytes of ROM and 512 bytes of RAM contained in a chip card. Such large memories speed up arithmetic operations considerably, and are a must considering that cards are used with 'signatures' having a length of 512 bits, and algorithms with an iteration depth of up to 32 bits to encrypt a single block of clear text (64 Bytes). The large ROM area provides sufficient space for program, look-up and encryption tables. The EEPROM locations are usually reserved for the option of running several applications on a single card.

To the electronics hobbyist, only the all-EEPROM based chip cards are of possible interest. These contain a processor running a program which only arranges the data transfer to and from the EEPROM, and takes care of the serial communication section. Using these basic utilities, certain (expired) intelligent phonecards may be given a 'second application' using the read-only mode. Most ordinary phonecards, however, are useless once their credit is used up.

Manufacturer Type	CPU	RAM	ROM	EEPROM
Siemens SLE 44xx	8 Bit 8051 derivative	128 Byte	4 kByte	2 kByte
Motorola 68HC05xx	8 Bit 6805	128 Byte	6 kByte	3 kByte
SGS ST9	8 Bit 6805 derivative	256 Byte	20 kByte	1.5 kByte
Toshiba TOSMART	8 Bit Z80 derivative	512 Byte	8 kByte	8 kByte
Hitachi H8/310	8 Bit H8	256 Byte	10 kByte	8 kByte
Philips 83C852	8 Bit 80C51 derivative	256 Byte	6 kByte	2 kByte
OKI MSM627xxx	8 Bit 8051 derivative	448 Byte	14 kByte	16 kByte

950036 - 19

Table 2. Overview of microcontroller products and their main features related to chip cards

Identification

The way chip cards identify themselves is standardized and referred to as 'answer-to-reset' in ISO 7816-3. The card reads a ROM-resident 128-bit wide recognition word (max. 256 bytes with other cards) containing, amongst others, manufacturer data (protocol T=1). This word is copied to the card reader via the I/O pin. The designation T=_ refers to a special protocol which is also specified in the ISO standard. Currently, there is T=0, T=1 and T=14.

Cards and countries

Unfortunately, the use of one and the same chip card for a single application (for instance, making use of a public telephone anywhere in Europe) is hindered by difficulties in equalizing (to a certain degree) the tariff structures used in the telecommunications field, as well as by the lack of identical concepts for secure storage of the card's residual value. The two problems are caused by the fact that a number of currently applied protocols

are tailored to one application only. Market areas formed by country-specific users have caused the introduction of different protocols and sub-protocols into the standard.

Although the 'answer-to-reset' procedure is able to identify the protocol used by the card, that does not mean that the reader system actually supports that particular protocol. Consequently, it is not yet possible to speak of overall compatibility or, indeed, of the cross-frontier and totally application-independent chip card.

Compatibility so far only means that any chip card's contact area is to the ISO standard, and that the reader performs a standard identification check when the card is inserted.

Answer-to-reset obviously works on processor cards as well as on their simpler counterparts, memory cards. The identification word provides information on electrical and interface data including

- position of the MSB in the dataword;
- communication protocol;
- clock frequency (internal/external);
- programming voltage (internal/external).

By modifying the associated software, and, possibly, the interface, the card reader presented in a future article in this magazine is capable of reading chip cards from different countries, and designed for different applications.

Protocol

The initialization sequence shown in Fig. 6 should be used to make the chip card supply its identification word. The word comes out in two chunks: the first has 16 bits reserved for the answer-to-reset function, the second, 112 bits containing various data as described below

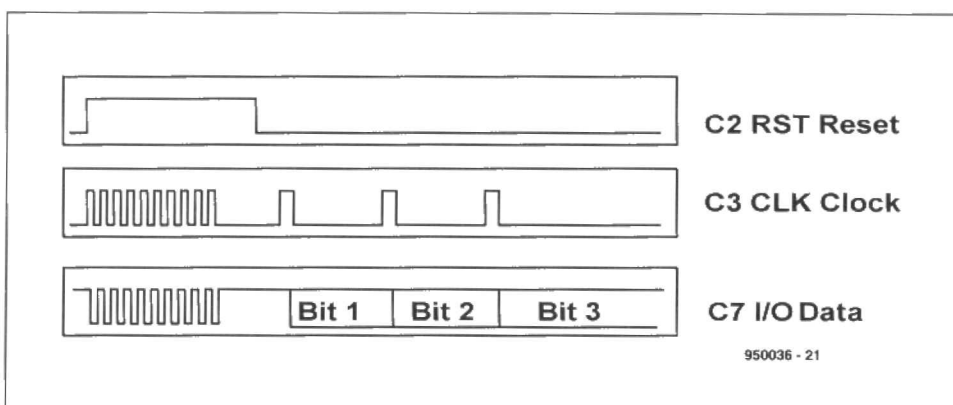


Fig. 6. Answer-to-reset pulse sequence.

address	number	function
000	16	Answer to Reset
016	8	11111111-dummy bits
024	4	manufacturer and first position of serial number
		0000 ORGA 0 N1
		1000 GDM 1
		0100 ODS 2
		1100 Gemplus 3
		0010 Solaic 4
	
		1111 Reserve 16
028	4	checksum
032	4	value of the new card
		1100 1,50 DM
		0010 6,00 DM
		1010 12,00 DM
		1110 60,00 DM
036	4	year of manufacture and second position of serial number
		0000 1980 + 10 N2
		1000 1980 + 10 + 1
		0100 1980 + 10 + 2
		1100 1980 + 10 + 3
		0010 1980 + 10 + 4
		1010 1980 + 0(!) + 5
	
		1111 1980 + 0 + 16
040	4	month of manufacture (0...11)
		0000 January +01 N3 N4
		1000 February +02
		0100 March +03
	
		1101 December +12
	
		1111 +16
048	4	serial number N9
052	4	serial number N8
056	4	serial number N7
060	4	serial number N6
064	8	residual value of card MSB number of 1-B a
072	8	residual value of card Bits b
080	8	residual value of card c
088	8	residual value of card d
096	8	residual value of card e
		residual value of card in pence = $a \cdot 8^4 + b \cdot 8^3 + c \cdot 8^2 + d \cdot 8^1 + e \cdot 8^0$
104	24	dummy bits 11111...1

950036 - 20

Table 3. Functions of the bits sent out by a disposable phonecard (having a fixed equivalent value). Example based on a Bundespost (German PTT) phonecard.

and shown in Table 3. The description is based on the assumption that a Bundespost (German PTT) telephone card is inserted into the reader.

Manufacturer (bits 24 through 27): a distinction is made between the manufacturers of the raw materials and the parts (chips) on the one hand, and the manufacturer of the assembly (the chip card itself) on the other.

Value of the new card: two different fields allow the card reader to establish the total value of the card at manufacture, and the remaining value (once credit units have been used up). The 'full' value of the card allows two different tariff rates to be used automatically, for instance, 25 pence per unit on a card worth £5, or 20 pence per unit on a card worth £20.

Date of manufacture: this indicates year and month of production. This is not the same as the date printed on the card.

Serial number: this is the serial number of the chip. It consists of nine numbers, N1 through N9. These numbers are appended to the previously mentioned information, and are read from bits 24 through 60.

Data encryption

Obviously, data on credit cards and, say, health insurance cards is strictly confidential and has to be protected against copying and other forms of misuse. Data on chip cards is therefore encrypted to one of the following standards:

- DES (data encryption standard), developed by IBM in 1977, is still among the simplest, safest and widest used algorithms.
- FES (fast data encryption standard) is a smaller version of DES using a shorter key. The system offers higher processing speed at the cost of reduced

data security.

- DSA (digital signal algorithm), developed in 1991 by the NSA (National Security Agency) for the purpose of authenticity checking.
- IDEA (international data encryption algorithm), patent applied for in 1991.
- RSA Rivest, also known as the 'Shamir and Adleman public key' method.

When picking what looks like the best algorithm, the computing power of the microcontroller used should be taken into account to ensure a reasonable trade-off between the duration of read/write operations and data security.

Applications

Phonecards are available in two versions: cards with a credit function (where the cost of the call is automatically drawn from your bank or girobank account), and the far more successful cards with a fixed equivalent value or a fixed number of cost units, for instance, 10 or 50 units. Although not personalized, the latter are still unique because each one has a unique serial number. Instead of throwing used-up telephone cards away, it would be possible to use them as personal identification cards in a simple controlled access system to an office or an apartment building, with door locks controlled by a card reader and a microcontroller. Taking this a bit further, it would also be possible to extend such a system with a 'person in/out' recorder coupled with time logging.

(950036)

For further reading:

Amphenol, chip card product information C702-X, C703, C704, C705, C707, C708.
OKI, Smart Card product information.
ISO 177, DIN 66003, ISO 7810, ISO7811/1, ISO 7811/2, ISO 7811/3, ISO 7811/4, ISO 7811/5, ISO 7816-1, ISO7816-2, ISO7816-3, ISO 7816.
ANSI Data Encryption Algorithm 1, DES X3.92-1991.

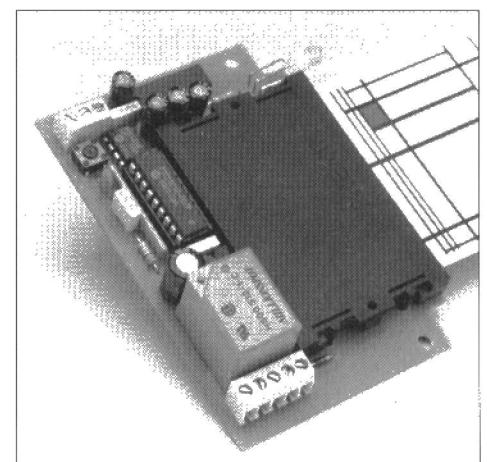
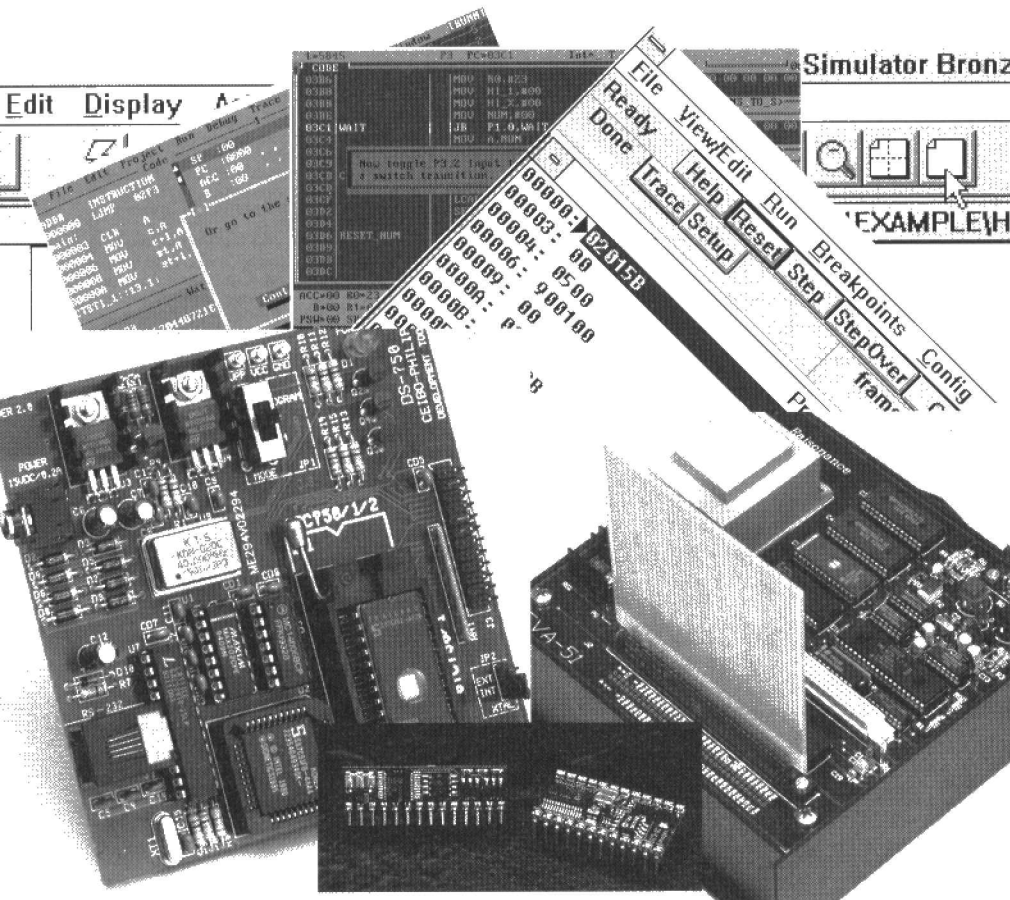


Fig. 7. An inexpensive and simple card reader with PCB contacts and an end switch.

ELEKTOR ELECTRONICS APRIL 1995



- the **80xx** series from Intel, which was the first to be available in large quantities, and are currently second-sourced by many manufacturers, including Philips and Siemens;
- the **ST62** series from SGS-Thomson Microelectronics;
- the **PIC** series from Arizona Microchip Technology, with its famous derivative, the 'Basic Stamp' from Parallax Inc.;
- the **68HC11** series from Motorola, which is very popular with amateurs and professionals alike.

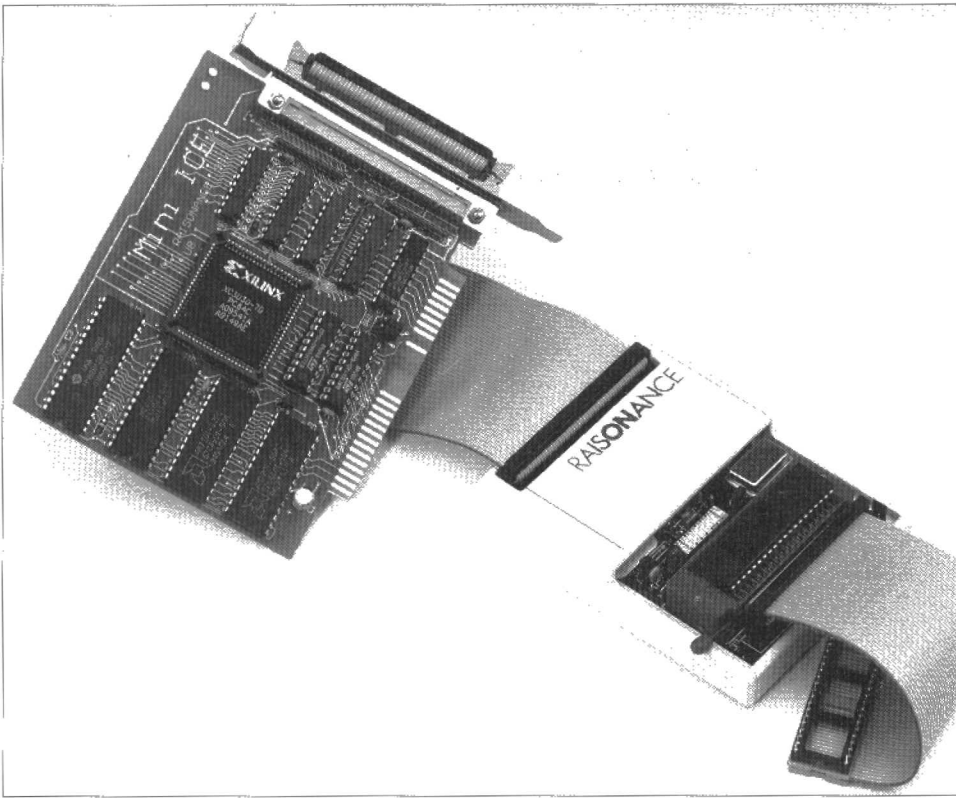


Fig. 1. Typical example of a microcontroller system development tool. This is a mini-emulator (courtesy Raisonance).

Development Environment, or IDE. The IDE is aimed at giving the user ready access to any development tool he or she wishes to use. The number of IDEs running under Windows is increasing rapidly. These are the features which should be offered by a good development environment:

- an easy-going and efficient user interface, which assumes the use of
- a multi-windows editor;
- mouse control;
- a quasi-automatic assembler-to-object code translator;
- an interactive on-line help function;
- a notepad to record useful jottings during the development phases.

Most assemblers come complete with a binary-to-IntelHex file format converter. The IntelHex format is the standard for most development systems and evaluation boards.

Cross assemblers, like the CROSS-32 meta-assembler from Isit, are capable of compiling object code for many types of microcontroller (which are then called *target devices*). The advantage of working with a cross assembler is that it allows you to work with more than one type of microcontroller.

Hardware in mixed systems

Although nearly all development tools for microcontrollers include some hardware, systems based on hardware only are very rare. The hardware may be classified as follows:

- development cards;
- evaluation cards;
- kits and starter kits;
- emulators.

In general, an emulator should have the following abilities:

- trace in real time;
- set breakpoints;
- operate in single-step mode;
- measure periods;
- visualize memory usage.

Spread throughout this article are screen snapshots of emulator programs running under DOS and Windows.

The iC181 is an example of a very powerful in-circuit emulator. Depending on the plug-in socket or adaptor used, the iC181 emulates almost anything from a Z80 to an 8085, not forgetting the HD64189, 68HC11, 80C552, 515, 517, 31/32, 535,

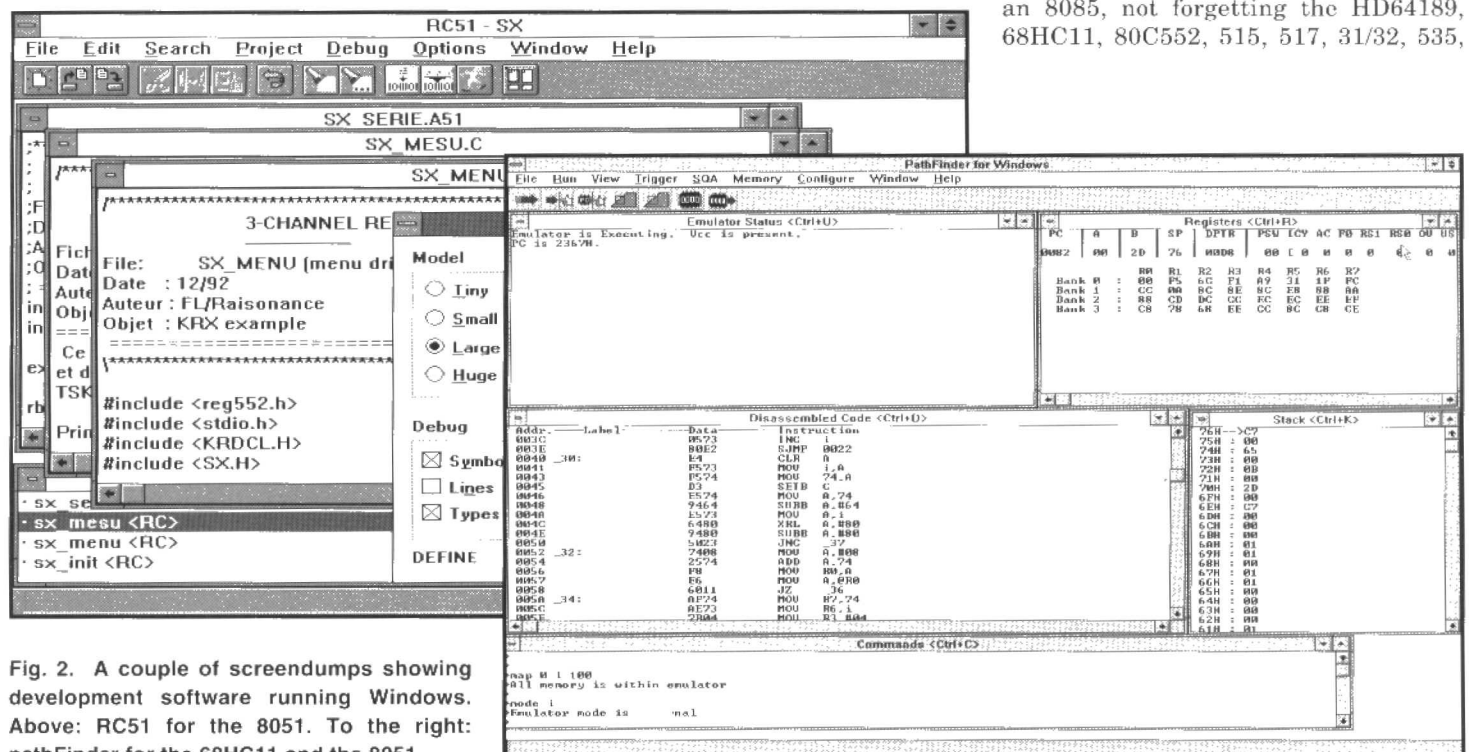


Fig. 2. A couple of screendumps showing development software running Windows. Above: RC51 for the 8051. To the right: pathFinder for the 68HC11 and the 8051.

4-bit Microcontrollers

OKI

OLMS64K series: MSM64162, MSM64164C, MSM64172, MSM64167*, MSM64169*, MSM64152/L, MSM64153/L, MSM64155/L, MSM64158/L, MSM64431, MSM644481*

Toshiba

TLSC-42 series: TMP42C00Y, TMP42(C)40P, TMP42(C)50N, TMP42(C)60N, TMP42C66P, TMP42(C)70N.

8-bit Microcontrollers

Motorola

68HCXXX series: 68HC11, 68HC711, 68HC811 and their derivatives.

6X0X series: 6809, 6309.

Intel

MCS@51 series: 8X31, 8X51, 8X32, 8X52, 8XC54, 8X58, 8X152.

MCS@-96 series: 8XC194, 8XC196.

Atmel

AT89 series: AT89C51, 8XC51, AT89C52, AT89C2051, AT89D52

Philips Semiconductors

MAB84XX series.

PCF84CXXXA series.

PCD33XA series.

8XXX series: 8051, 8XC750, 8XC748, 8XC751, 8XC749, 8XC752, 80C31, 8XC51, 8XC451, 8XC550, 8XC851, 8XC542, 83C852, 8XC575, 83C055 and many others.

SGS-Thomson Microelectronics

ST6 series: ST6210, ST6215, ST6220, ST6225, ST6240, ST6242, ST6245, ST6260, ST6265.

National Semiconductor

COP800 series: COPC912, COPC820, COPC840, COPC880, COPC8780128, COPC8620, COPC8640.

COP888 series.

Toshiba

TLCS-870 series: TMP87PH00N/F, TMP87PH20/F, TMP87PM40N/F, TMP87PH40N/F, TMP87PH46N, TMP87PH47U, TMP87PS64F, TMP87PM78F1K.

TLCS-90 series: TMP91P640, TMP90PM40, TMP90P802AP, TMP90PH48F.

Siemens

8X5X series: SAB80515, SAB80C535, 83C515A-A, SAB80C517, SAB80C537, SAB83C517A-5.

C500 series: SAB-C501/502/503.

Arizona Microchip Technology

PIC16CXX series: PIC16C54, PIC16C55, PIC16C56, PIC16C57, PIC16C58A, PIC16C64, PIC16C71, PIC16C74, PIC16C84.

PIC17CXX series: PIC17C42

Dallas Semiconductor

SoftMicro series: DS5000(T)-X-Z, DS2250-X-Z, DS2251-X-Z, DS2252-X-Z

These are special devices. The first x in the type number indicates the size of the memory in kBytes. The z indicates the clock speed in MHz. Thus a DS5000T-32-16 has 32 KBytes of internal RAM, and runs at 16 MHz. These devices come in a 40-pin SIMM enclosure, and have an 8051 compatible interface, a non-volatile RAM of 8, 32 or 64 KByte, and a built-in serial bootstrap loader.

DS8XCXX series: DS80C320, DS87C520, DS80C530

Hitachi

H8300 series: H8/322, H8/323, H8/324, H8/325, H8/3256, H8/3257, H8/326, H8/327, H8/328, H8/329, H8/330, H8/332, H8/3334, H8/336, H8/337, H8/338, H8/350

H8/500 series: H8/520, H8/532, H8/534, H8/536, H8/534S, H8/536S, H8/538, H8/510

OKI

OLMS65K series: MSM65511, MSM65512, MSM65513, MSM65514, MSM65516, MSM65524, MSM65544, MSM65x227, MSM65352, MSM65355, MSM644481.

Texas Instruments

TMS370 series: TMS370C010, TMS370C310, TMS370C311, TMS370C610, TMS370C710, TMS370C020, TMS370C022, TMS370C320, TMS370C322, TMS370C622, TMS370C722, TMS370C032, TMS370C332, TMS370C732, TMS370C040, TMS370C042, TMS370C340, TMS370C342, TMS370C642, TMS370C742, TMS370C050, TMS370C056, TMS370C058, TMS370C150, TMS370C156, TMS370C250, TMS370C256, TMS370C350, TMS370C052, TMS370C352, TMS370C356, TMS370C058, TMS370C358, TMS370C756, TMS370C758.

8/16-bit Microcontrollers

Intel

MCS@ 251 series (8/16/32 bit registers).

OKI

OLMS66K series: MSM66101, MSM66201, MSM66417, MSM66507, MSM66509.

SGS-Thomson Microelectronics

ST9 series: ST9020, ST90R26, ST90(x)27, ST90(x)28, ST90(x)30, ST9036, ST90(x)40, ST90R50, ST90R51, ST92(x)91, ST92(x)93, ST92(x)94

16-bit Microcontrollers

Intel

MCS@96 series: 8xC196

Fujitsu

F2MC-8L/8LC series: (MB89xxx): MB89121, MB89123A, MB89125A, MB89P131, MB89131, MB89P131, MB89133A, MB89135A, MB89144, MB89145, MB89146, MB89147, MB89151/A, MB89152/A, MB89153/A, MB89154/A, MB89145/A, MB89161/A, MB89163/A, MB89165/A, MB89173, MB89181, MB89182, MB89183, MB89191, MB89191A, MB89193, MB89193A, MB89623, MB89625, MB89626, MB89627, MB89635, MB89636, MB89637, MB89643, MB89645, MB89645, MB89646, MB89647, MB89653A, MB89655A, MB89656A, MB89657A, MB89663, MB89665, MB89673, MB89675, MB89677A, MB89816, MB89821, MB89823, MB89846, MB89855, MB89857, MB89665, MB89667, MB89675.

Siemens

C16X series: SAB-C165, SAB-C167

SAB8XC166 series: SAB80C166 SAB83C166-5, SAB883C166-5

SAB-C167 series: SAB-C167-LM, SAB-C167-1RM

SAB-C165 series: SAB-C165-LM

OKI

OLMS67K series: MSM67620

Toshiba

TLCS-900 series: TMP96C141F, TMP96C041AF, TMP97C241F, TMP97PS40F, TMP97CS40F

Philips

Series based on 68000 *

*Processor based on 32-bits architecture.

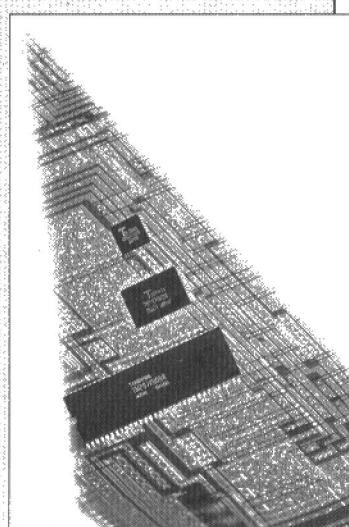


Fig. 4. Members of Toshiba's TLCS-870 family of controllers (courtesy Toshiba).

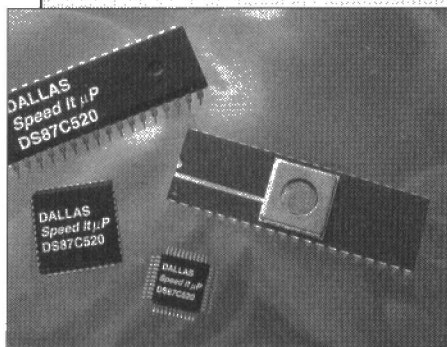


Fig. 3. With its 16 Kbytes of EPROM, 1.25 Kbytes of SRAM and all the rest, the DS87C520 from Dallas Semiconductor is an ultra-modern version of the generic 8051 (courtesy Dallas Semiconductor).

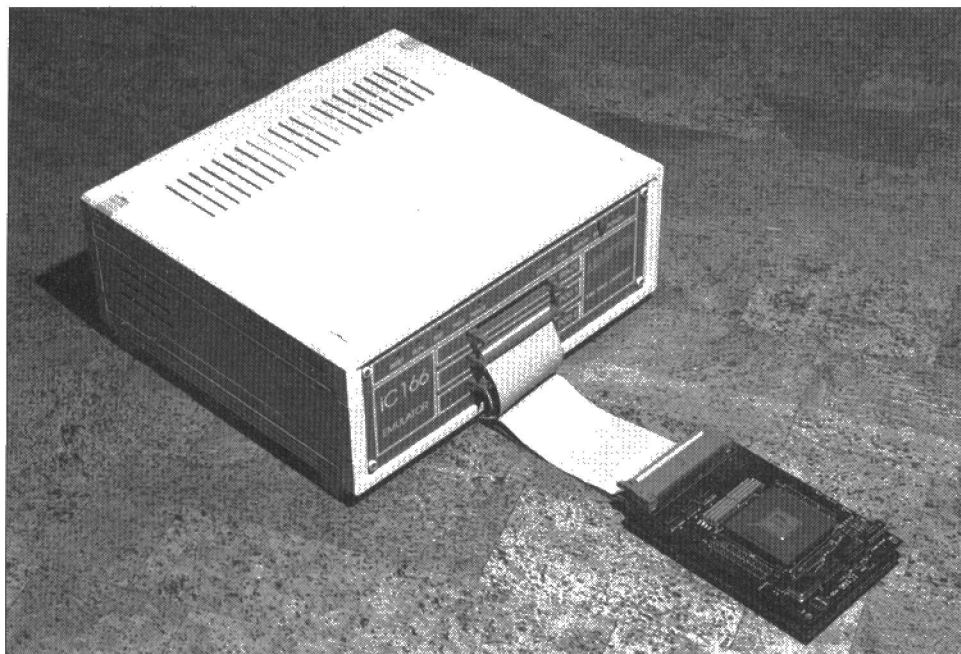


Fig. 5. The iC166 is a real-time emulator for the 80C166. The unit sports 256 KBytes of emulator memory, and 128 KByte for hardware breakpoints (courtesy iSystem).

537, Z180, 182, and many more. Impressive.

For the 80xx

Intel itself supplies a development kit for the devices in the 8XC196 family, containing an assembler (ASM-96), a 32-bit floating point library, a locator/relocator (RL-96), IC-96, PLM-96 and a converter which turns object code into hexadecimal. Also available is an ice (in-circuit emulator) system with a window interface, and a family of evaluation cards sold under the name EV80C196Kx. As re-

gards the popular MCS-51 family, Intel seems to rely on the expertise brought in by other, specialized, companies. Some relevant products are mentioned below. The list is not exhaustive!

Keil supply a wide range of extremely powerful products for the MCS51[®] and MCS251[®] families, including an assembler, compiler (C51 and C251), a real-time executive, a simulator and a starter kit. Also available is a macro assembler, A51 (or A251).

Hitex offer a simulator, a ROM monitor,

an evaluation card and an emulator.

Inform is into development systems based on fuzzy logic, more of which further on.

The MX51 from Hitex is an ICE which operates in conjunction with a development environment called HITOP which has some very sophisticated functions.

The 'TELETEST-51', also from Hitex, is capable of tackling more than 60 processors (status: September 1993), from the 8031 to the 83C851, and including some 'rare birds' like the 80CL410 and 83C662. This system is based on different probes (interfaces) for the processors supported.

Contrary to what you may associate with its name, 'TELEMON 8051' is a system designed to develop applications for the 8051, although its monitor calls for a 80C37.

Based on the TELETEST 51, the TX51 may be used with the ROM-less members of the 8051 family. This system is connected to the parallel port of the host computer.

The AX166 from Hitex is an in-circuit emulator specifically designed for the 80C166 family of controllers. It is backed by the HITOP development interface. HITOP166 and TELEMON166 together form a very effective debugging utility.

HISIM166 is a powerful simulator for Intel's 80C166 controller.

The MCB-167 evaluation card shows an interesting approach to development systems for the 80C166/ST10 controller. Actually, it contains an 80C167 which uses its bootstrap loader to copy the monitor — the 166 for dScope — into its RAM. The 166 is a source debugger consisting of a simulator and a target debugger.

FuzzyTECH[®] is the latest approach based on fuzzy logic, marketed by **Inform**. The



Fig. 6. Examples of microcontroller development software running under DOS.

fuzzy development environment draws heavily on graphics interfaces like Windows. *FuzzyTECH*® is available in versions for the 196, 166, 51 and other processors.

Siemens, like Intel, seems to leave development systems for their microcontrollers to others. Siemens produces, among others, the SAB80C510/2/3, SAB80C535/7, SAB80C515/15A/17 and SAB83C515A/17A, which are supported by a range of development tools from various suppliers based on Keil products. Raisonance (France) offers a number of emulators for Siemens microcontrollers.

Boston Systems Office (BSO) supplies development tools for the SAB80C166/167 and 165.

Ashling supplies emulators for the SAB80C166/167/165 from Siemens.

For the ST62 family

SGS-Thomson has different starter kits for their microcontroller products:

- ST6220 Starter Kit for the ST6210/15/20/24;
- ST6240 Starter Kit for the ST6240/42/45;
- ST626x Starter Kit for the ST6260/65.

The ST9 family is supported by

- ST9040 Starter Kit; this relatively low-cost system allows you to develop applications for the ST9 series of controllers, and contains hardware, software, a power supply, and components, to develop applications based on the ST90(x)xx.

Interestingly, there is also a *FuzzyTECH*® version for the ST6215.

For PIC controllers

Arizona Microchip has a range of tools to develop applications on the basis of their pic family of devices.

The PICMASTER™-16B, for example, is an in-circuit system emulator for PIC16C71 controllers. Running under Windows on a PC, it contains the programmer PROMATE™, assembler MPASM, logic simulator MPSIM, a few samples, a demonstration board, extensive documentation, an active probe card for the PIC16C71 and a programming socket. Impressive!

Similar products are the PICMASTER™-16C for the PIC16C84, the PICMASTER™-16D for the PIC16C54/54A/55/56/57 and 58A, the PICMASTER™-16E for the PIC61C64, the PICMASTER™-16F for the PIC16C74, and the PICMASTER™-17 for the PIC17C42. All of these are just as complete as the 16B version of the PICMASTER™. The contents of these kits is exemplary, and should set a standard in microcontroller land. Not surprisingly,



Fig. 7. Contents of the PICSTART-16C kit from Microchip Technology.

an increasing number of designers comes up with really interesting applications of PIC controllers (witness some recent articles in this magazine).

Arizona Microchip also offers a number of development kits for its PIC products. These are the PICSTART™-16b kit for the PIC16C54/54A/55/56/57 and 58A, PIC16C71 and PIC16C84; and the PICSTART™-16C for the PIC16C64 and PIC16C74. These development kits contain a programmer board for the relevant controller, an assembler, a simulator and host system software (including communication tools etc.), a few samples, a power supply, an RS232 linking cable and, last but not least, extensive documentation which, again, is so good and extensive that it sets a standard.

FuzzyTECH®-MP is a set of development tools for the PIC16C5x, 16C6x and 17C42. These tools include a demonstration board, a hardware protection key, an RS232 connecting cable, samples of the PIC16Cxx, a multi-purpose power supply and documentation.

On a different tack, but still from Arizona Microchip, is the PROMATE™ kit which enables all members of the PIC16C5X, 16Cxx and 17Cxx to be programmed. Apart from a versatile programmer, the kit also contains a power supply, software which combines the functions of assembler and simulator for the PIC16Cxx and PIC17Cxx, an RS232 connecting cable, and extensive documentation.

The PICPROBE™-16 and PICPROBE™-17 series from Arizona Microchip contains adaptor modules which allow the PICMASTER™ emulator systems to be set up for the different members of the PIC16/17 families. The kits include all the relevant hardware, software and doc-

umentation.

Microchip's PICDEM-1 and PICDEM-2 are simple plug-and-play boards aimed at demonstrating the capabilities of the PIC microcontrollers.

Finally, contained in some of the kits mentioned above is an assembler for the PIC16C5x/Cxx and PIC17C42, and/or a simulator for the PIC16C5x/Cxx. The assembler is capable of generating a number of output file formats.

Parallax Inc. supplies the Basic Stamp®, a single-board computer based on a 16C5x PIC controller, as well as a range of other products related more generally to the PIC microcontroller. A brief overview of these excellent products is given below.

► Assembler for PIC16Cxx

This product converts the source code of a program written in assembler language into a block of object code which may be used by simulators and programmers.

► Logic simulator for PIC16Cxx

This piece of software simulates the execution of PIC programs on a PC screen. It is possible to do this in step-by-step mode, or by setting breakpoints and then checking what actually happens inside the processor by studying the data presented in a window. Many software developers use this simulator for experiments, and to do the initial debugging rounds. The simulator may also be used in conjunction with I/O simulators, and other in-circuit emulators.

► PIC16Cxx programmer

This piece of hardware enables you to program, read and verify PICs. A single-screen control program greatly simplifies

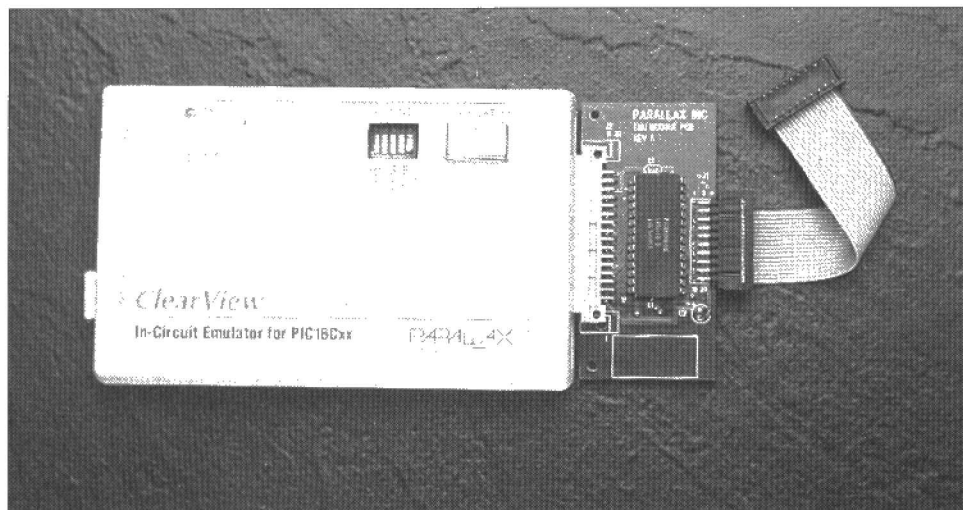


Fig. 8. The ClearView in-circuit PIC16Cxx emulator from Parallax Inc. can run at a clock speed between 32 kHz and 20 MHz.

the programming work.

In spite of its small size, the programmer has an extension connector which allows the use of different types of adaptor, an 18/28 or 40-way ZIF socket, an 18/28-way SOIC socket, or a 20/28-pin SSOP contact. Actually, this programmer is all you need to get started with these fascinating devices called PICs.

► **BackDraft17™** is the latest programmer launched by Parallax for the PIC17C42.

► **Unloader for PIC16C5x**

This device acts as a ROM emulator for the PIC16C5x, which it replaces in the target system. The unload operation is the 2-second equivalent of a much longer 'real world' cycle which normally comprises programming, clearing and removing the device from the board.

► **TrueFlight**, a programmer/unloader for the 71/84

This unit forms a novel approach, combining a programmer with an unloader

for the PIC16C71 and PIC16C84. It contains an UV light source for clearing (window-type) PICs before they are programmed again. The TrueFlight is the 'Swiss Army Knife' for PIC development systems.

► **Reflection**, an I/O simulator

This system actually replaces the PIC in a circuit, and operates as a kind of I/O extension to the logic simulator. Under software control, the hardware part of Reflection reads the inputs among the I/O lines, and similarly writes to the outputs. Since the software simulates program execution on a PC, the hardware produces the corresponding action on the I/O pins of the circuit under test. Pushing the limits of the circuits, this system allows problems to be detected which would normally be very hard to locate. This emulation technique is relatively slow because it is controlled by a PC. But then, one must never be too hurried when developing a microcontroller based application.

Parallax supplies another in-circuit emulator, ClearView '5x™, which handles nearly all PICs. This tool is marked by an interchangeable oscillator capable of operating at any frequency between 32 kHz and 20 MHz. The ClearView 'xx™ uses extension modules to adapt itself to different types of PIC controller.

C compilers are available, one for the PIC16Cxx, and another for the PIC16C17xx, at reasonable cost.

The BASIC Stamp comes with a few utilities contained in the programming kit: a cable to connect the Stamp to the PC, a program editor, and documentation.

Among the many other suppliers of 'tools for the PIC trade' are **Advanced Transdata Corp.**, who make program-

mers, ICEs, and combination systems comprising of an unloader, emulator and a programmer, as well as real-time emulators (RICE, real-time in-circuit emulator).

Advin Systems, Inc. is on the market with universal programmers. **Application Solutions, Inc.** supply a programming/demonstration card. Other manufacturers of programmers are **BP Microsystems**, **Citadel Products Ltd.** and **Data I/O**. As an aside, most of today's multi-device programmers are capable of 'burning' PICs.

For the 68HCxx family

The flagship of Motorola's 'small' microcontroller series, the 68HC11, is supported by a number of development tools from different manufacturers.

Mecalogic, for instance, supplies the MHC811EME 'embedded emulator' which allows any program to be fine-tuned within the application circuit, requiring no other tool than a PC hooked up to the RS232 interface. This product, in the development package version, is actually a board containing its own microcontroller and, depending on the exact version, different types of memory, zero-power RAM and/or EEPROM linked to a source editor, an assembler which supplies object code, a direct debugger, an RS232 cable and a mains power adaptor.

Also from Mecalogic is the HC711D3 card, aimed at the MC68HC711D3 controller. This card, which is much larger than the MHC811EME, comes with a source code editor, an assembler and a real-time emulator.

I.S.I.T. offers several emulators, including the WICE68HC11, a low-cost but very powerful 68HC11 emulator, and the IC181 professional multi-family emulator.

And others ...

For the Texas Instruments TMS320 controller, for instance, **Convergie (France)** offers a version of *FuzzyTECH*.

Software-only products

One of the most spectacular ways of designing a microcontroller system is without doubt the 'software-only' method. As far as we have been able to ascertain, the only product in this field is **The Realizer** from **Actum Solutions**.

As illustrated by the screendumps in Fig. 11, all functions offered by the Realizer are based on software only. Since many of you may be unfamiliar with the concept of system design based on software only, a brief rundown of the basic operation of The Realizer is given below.

Having chosen an existing project, or given a name to a new project, you can get to work. The first phase consists of drawing the logic diagram of the circuit with its sub-units. Next, you go through

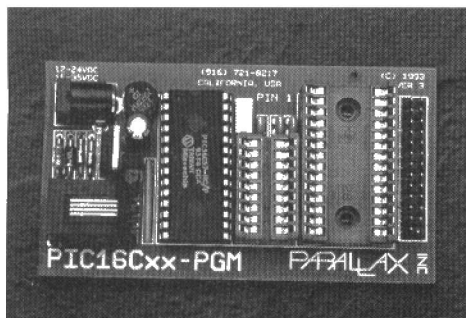


Fig. 9. This miniature programmer from Parallax is capable of programming all PIC16xx devices, as well as reading and verifying PIC16C5x, PIC16C64/74 (with an adaptor), PIC16C71 and PIC16C84 devices (courtesy Parallax Inc.)

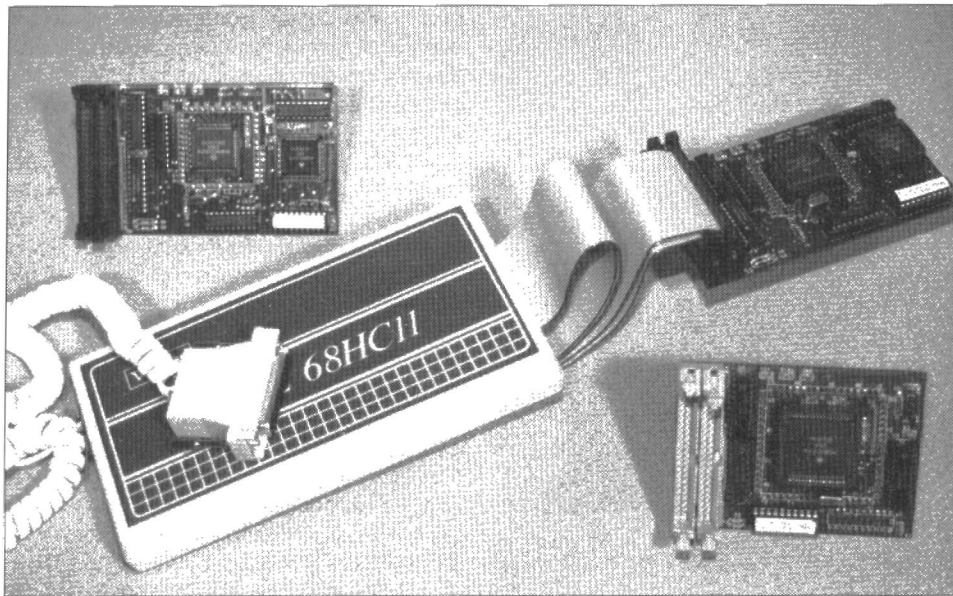


Fig. 10. The WICE68HC11 emulator can be fitted with one of three pods to connect to different types of microcontroller application circuits.

an analysis phase, during which the program checks that everything is in accordance with the design rules. Next, the program does a simulation round, showing the states of outputs, and the value of variables, using graphics if so required.

Once you have your 'ok' for the different stages of the process, it is time to select the hardware configuration you wish to implement, in other words, the target processor for which the code should be written. This is done during the final design phase, with the aid of an assembler for the relevant processor/controller.

A new version of The Realizer, v2.0, runs under Windows. It is still being developed, and Actum hope to release it later this year. Like the DOS version, the

Realizer 2.0 supports the following processors and microcontrollers: 8051 and its derivatives, the ST62 family, the PIC16 family, the 68000 family, and the ANSI-C code.

The Realizer comes with a library containing some 60 symbols to help you design the most up-to-date of circuits. The program allows you to design custom symbols, and implement their functions in assembler. The Realizer offers you a choice between (1) keeping the size of the RAM used by the target program as small as possible, (2) the same for the size of object code or (3) non-used (sleeping) code, or (4) tuning the software for the highest possible speed. On-line help is available all the time in the Windows version.

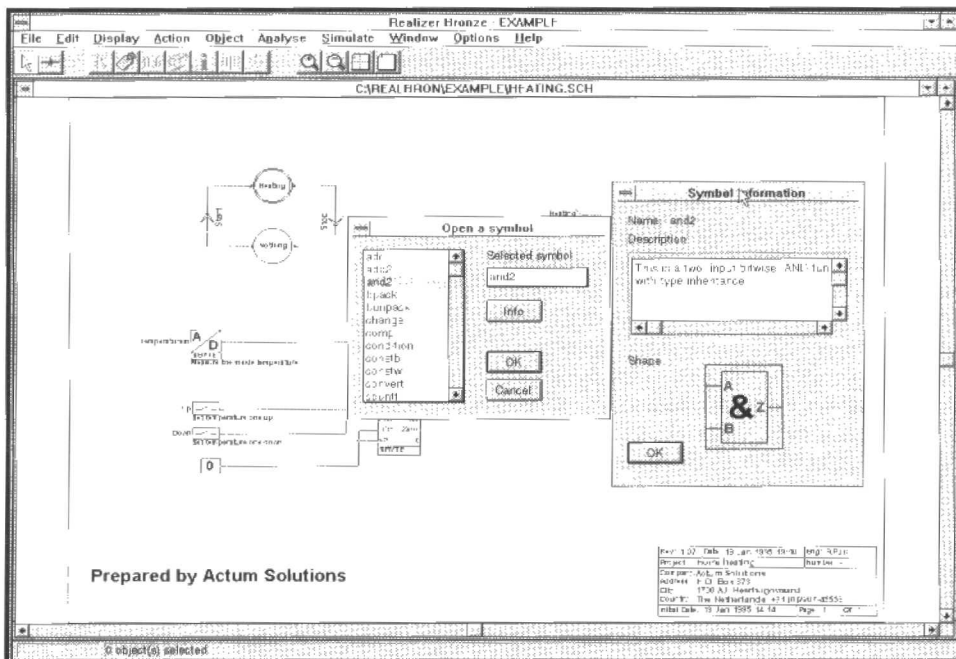


Fig. 11. The Realizer from Actum Solutions in action.

The program reports on the results of a simulation run by means of visualization objects such as switches, fuses, scope screens and signal generators.

(950019)

Some useful addresses:

Microchip Technology, Inc., 2355 West Chandler Blvd., Chandler, AZ 85224-6199, U.S.A. Tel. (+1) 602 786 7200, fax: (+1) 602 899 9210.

UK Headquarters: Unit 6, The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks SL8 5AJ. Tel. (01628) 851077; fax (01628) 850 259.

Parallax, Inc., 3805 Ahterton Road, #102, Rocklin, CA 95765, U.S.A. Tel. (+1) 916 624-8333. Fax: (+1) 624-8003. BBS: 624-7101. In the UK, contact **Milford Instruments**, Tel. (01977) 683665, fax (01977) 681465.

Actum Solutions, P.O. Box 373, NL-1700-AJ Heerhugowaard, The Netherlands. Tel. (+31) 2207 45553.

Keil and Hitex products: Hitex (UK) Ltd., Warwick University, Science Park, Coventry CV4 7EZ. Tel. (01203) 692066, fax: (01203) 692131.

Crossware Products, Melbourn, Royston, Herts SG8 6BA. Tel. (01763) 261539, fax: (01763) 262983, BBS: (01763) 261716.

MicroAmps Ltd., 66 Smithbrook Kilns, Cranleigh, Surrey GU6 8JJ. Tel. (01483) 268999, fax (01483) 268397.

B.H. Systems Ltd., Lighthouse Buildings, Rattray head, Peterhead, Aberdeenshire AB42 7HB. Tel./fax (01346) 532236.

John Morrison, 4 Rein Gardens, Tingley, W. Yorks WF3 1JR. Tel./fax (01532) 537507.

Raisonance, Z.I. Rue des Sources, F-38920 Crolles, France. Tel. (+33) 76 081816, fax: (+33) 76 080997.

Mecalogue Concept, BP 24, F-13540 Aix-Puyricard, France. Tel. (+33) 42 922644, fax (+33) 42 922645.

Data I/O Corporation, 10525 Willows Road N.E., P.O. Box 97046, Redmond WA 98073-9746, U.S.A. Tel. (+1) 800 332-8246, fax. (+1) 206 869-7423, BBS (+1) 206-882-3211.

Advanced Transdata Corporation, 14330 Midway Road, Suite 104, Dallas TX 75244. Tel. (+1) 214-980-2960, fax (+1) 214-980-2937, BBS (+1) 214 980-0067.

BP Microsystems, Inc., 1000 N.Post Oak Road, Houston TX 77055, U.S.A. Tel. (+1)-713-688-4600, fax. (+1) 713 688-0920, BBS (+1) 713 688-9283.

Citadel Products Ltd., 50 High Street, Edgware, Middx HA8 7EP. Tel. (0181) 951 1848, fax (0181) 951 5857.

Advin Systems, Inc., 1050-L East Duane Ave, Sunnyvale CA 94086, U.S.A. Tel. (+1) 408-243-7000, fax (+1) 408 736-2503, BBS (+1) 408 737-9200.

UK distributors: **Quarndon Electronics**, Tel. (01332) 32651, fax (01332) 360922.

Application Solutions Ltd., Tel. (01273) 476608, fax (01273) 478888.

I.S.I.T., Z.I. des Poumadères, F-32600 L'Isle Jourdain, France. Tel. (+33) 62 072954, fax (+33) 62 072953.

THE DIGITAL SOLUTION

Part 5 – Storing data

By Owen Bishop

In this series we look closely at digital electronics, what it is, what it does, how it works, and its promise for the future.

Knowledge is power. Knowledge stored in written or printed form, whether it be the Yellow Pages, a nautical chart or a computer handbook, gives power to the person who has access to it. As far as possible, access must be easy, fast and cheap. For thousands of years, libraries have been the most important large-scale stores of information. We include works of fiction and works of art such as music CDs among the information stored there for, although they may not supply us with irrefutable facts, they tell us about the culture, the times or the personalities of the authors and artists who produced them. The problem with libraries is the ever-increasing volume of information, demanding more and more storage space. Already, many libraries have no room on their open shelves for the whole of their collections. Less-frequently consulted works have to be stored away in less accessible sections, contrary to the need for easy access.

One way of countering the expansion of published information is to reduce the physical size of the documents. Microfiche has been used successfully for this purpose, and many journals and archives are or were published in this form. But microfiche, though more accessible in the sense that the equivalent of the shelf-full of books can be held in one hand, still requires the reader to 'turn the pages'. No matter how systematically the data is arranged on the microfiche, it takes an appreciable time to scan the rows and columns of images.

The digital solution is to store data in the memory of a computer, where it can be accessed at high speed and where it is possible to implement search routines to take the user direct to the information required. With the advent of multimedia systems on home computers, anyone can have an encyclopaedia, a dictionary of quotations, an atlas,

a world almanack, a history book, a book of facts and a thesaurus on Microsoft's *Bookshelf* CD-ROM at a very affordable cost. With searching and cross-reference facilities bridging all the 'books' on the shelf, digital techniques are making knowledge, and therefore power, available on a much wider scale than hitherto. As computer networks proliferate, we shall be able to obtain instantly an increasingly wide range of information worldwide, simply by keying in a few commands at the computer keyboard.

Data storage

To understand how these information systems are being realised, let us look at the way a single unit of information may be stored. The single unit of information is the binary digit or *bit*. We represent it by one of its two possible states, '0' or '1', corresponding to truth or falsehood. Depending on the context, a binary digit may have one of many meanings, such as: 'the car park is full/not full', 'the account is in credit/debit', or 'the person is

over/under 60 years old'. In a different context, and together with a few thousand other bits, it may represent a note from a performance of Beethoven's *Fifth Symphony*.

One way of storing a bit is to use a circuit known as a bistable (US: flip-flop). Later we shall look at an even simpler circuit, but the bistable is the conventional storage unit. This circuit can exist in either one or two stable states, with one transistor switched on, the other switched off. Suppose that in Fig. 39 Q_0 is on and Q_1 is off. The LED is not lit and we take this to mean that the bistable is storing a 0. If we apply a negative pulse to input 1 (for example, by briefly grounding it), the base current to Q_0 is interrupted, turning the transistor off. As a result, Q_1 is turned on and the LED is lit. The bistable has changed

to its other stable state and is now storing a 1. Grounding input 1 a second time has no effect, but, if input 0 is grounded, the circuit changes back to its original state, storing 0. This circuit can 'remember' which of its inputs was most recently made low.

We have talked about grounding the inputs, but the triggering input could come instead as a low-going pulse from a sensor circuit or from another logic circuit, applied to one or other of the input terminals. The indicator LED in Fig. 39 is not an essential part of the bistable; instead, the value (0 or 1) of the stored data can be read by logic circuits connected to the output terminal.

Figure 39 is only one of the many possible ways of building a bistable. We also make them from JFETs, op amps and MOS-FETs, usually as ICs. The bistable shares with many others kinds of memory circuit the fact that the data is lost when the power is switched off. When the power is switched on again, the state into which the bistable goes depends on slight differences

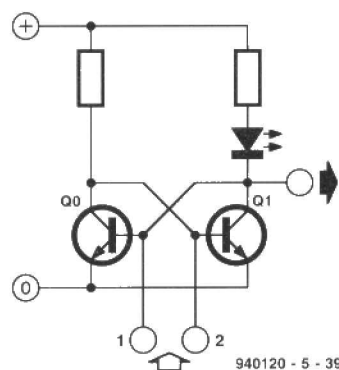


Fig. 39

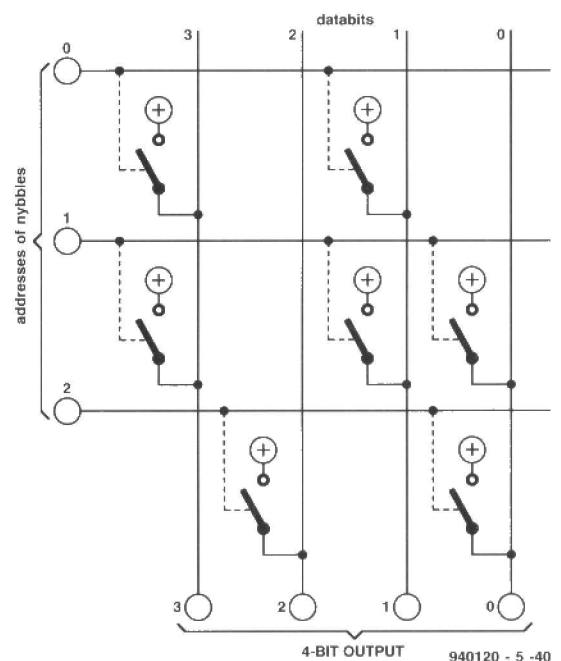


Fig. 40

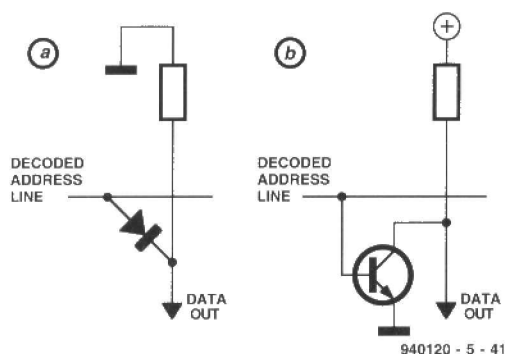


Fig. 41

between the two resistors or the two transistors, not on the data that was previously stored. This kind of data storage is described as being *volatile*. Storing data in a short-lived way is quite unlike storing data in books and libraries, but is entirely acceptable for data that is continually changing. One of the commonest instances of the use of bistables for temporary data storage is the memory of a computer, which we discuss later, but first we consider permanent data storage.

Permanent storage

Digital techniques include two main ways of permanent data storage, both of which are the equivalent of the printed or hand-written document. One technique is purely electronic, the other involves a recording medium such as magnetic tape. We look at electronic techniques now and discuss recording media next month. The electronic equivalent of the printed book is the *Read Only Memory* or ROM. Just as the data stored in a book is placed there when it is printed, so the data stored in a ROM is placed there when it is manufactured. To store any

significant amount of information, a ROM must be capable of storing more than a single bit. Generally, ROMs store several thousands or even millions of bits.

With so many bits to store, it is essential for them to be organized in a systematic way and for us to have some means of accessing the particular bit or group of bits that we require. One of the ways in which this is done is shown in **Fig. 40**. The bits are organized into groups of four, so that one group represents a 4-bit binary number or code, known as a *nybble*. We have restricted the size of the group to four bits to make the diagram simpler. Although some ROMs do, in fact, access the bits in fours, it is more usual for them to be stored in groups of eight, known as *bytes*. In **Fig. 40**, there are four data lines (numbered 0 to 3), one for each of the bits in the nybble. There are three address lines (numbered 0 to 2), one for each of the nybbles stored in this ROM. Thus, the *organization* of the memory section of this very simple ROM is three nybbles, each of four bits. This makes a total of 12 memory units, or memory *cells*. The data for each nybble is stored in four cells.

So that we can gain access to one particular nybble, the ROM IC also needs an *address decoder*. This is a simple logic circuit, which takes the binary address supplied to it from an external control circuit and puts a logic high on the appropriate one of the address lines. The address decoder has a truth table as shown in **Table 1**. As this table shows, a 2-bit address covers all addresses from 0 to 3, but this ROM has no cells at address 3.

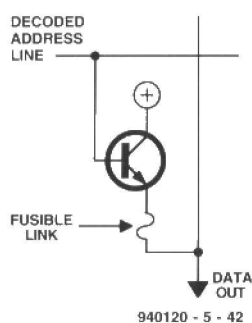


Fig. 42

Input		Output on address line		
B	A	2	1	0
0	0	0	0	1
0	1	0	1	0
1	0	1	0	0
1	1	not used		

Table 1

To follow how data is read from the ROM, suppose we want to read the data stored at address 1. The address inputs are set to 01, and the decoder makes address line 1 go high. This address line has the control inputs of three voltage-controlled switches connected to it as shown in **Fig. 40**. All three switches are closed when address line 1 is made high. This connects data lines 0, 1 and 3 to the positive supply rail. Data line 2 has no switch, so it is not connected to a data line. The result is that the output of the ROM becomes 1011, which is the data stored at address 1.

When the ROM is manufactured, the pattern of the mask produces a switching circuit where a 1 is to be stored and no connection where a 0 is to be stored. A ROM fabricated in this way is sometimes called a *mask ROM* to distinguish it from other kinds of ROM. Once the mask has been prepared, the pattern can not be altered. In consequence, it is possible to read data from the chip, but not to write data into it. This is the significance of the term *read only*.

The switching circuit in each cell of a ROM can take many forms, two more of which are shown in **Fig. 41**. At (a), we use a diode. Normally, the data line is held low by the connection to 0 V through the resistor. When the voltage on the address line exceeds the forward voltage of the diode, the data line goes high. In (b), the switch is a transistor. The line is normally held high, but a high voltage on the address line turns the transistor on, causing the output to go low.

A slightly different kind of switching circuit is shown in **Fig. 42**, with a *fusible link* between the transistor and the data line. When the chip is manufactured, *every* cell has a switch like this, so a byte-store chip has 11111111 stored at

every address. The ROM is prepared for use by *programming* it with the data that is to be stored in it. This type of ROM is known as a *programmable ROM* or PROM. Special programming equipment writes data into each address in turn. For a given address, the data lines that are to be 0s are connected to 0 V. A higher than usual voltage is applied to the address line. This causes the transistor to be switched on and a large current flows to the data line, large enough to fuse the link. This disconnects the data line from the transistor at that address; in effect, the transistor is no longer there. At each cell, an intact link (= switch present) is equivalent to a 1 and a destroyed link (= switch absent) is equivalent to a 0. The programming equipment is usually loaded with the data that is to be stored and automatically transfers it to the PROM.

PROMs can be mass-produced so they are much cheaper than mask ROMs. By contrast, mask ROMs are usually required in small numbers, so their price has to be relatively high if their production costs are to be recovered. This limits the use of mask ROMs to regularly-required applications, such as programs for the basic booting up system of a computer or for storing data for look-up tables. PROMs are more suitable for specialist equipment that is manufactured in relatively small numbers. They are also used in development prototypes, since a new PROM can be programmed each time the design of the equipment is refined.

Erasable memory

Once a fusible-link PROM has been 'blown', it is still possible to reprogram 1s to 0s, but it is not possible to reprogram 0s to 1s. For all practical purposes,

fusible-link PROMs are programmable only once.

Another class of PROM is the *erasable* PROM or EPROM. Data is stored into this by placing a charge on a capacitor. **Figure 43** shows the storage element and, as in the other types of ROM, these are usually arranged in addressable groups, nybbles or bytes. The element is an NMOS transistor with an unusual gate, which is completely insulated by being embedded in the silicon dioxide layer. With the gate uncharged, it is possible for electrons to pass from source to drain; the transistor is on and represents a 1. The transistor is programmed to become a 0 by placing a negative charge on its gate. A high potential difference between source and drain injects electrons into the gate. They remain there when the pd is removed, repelling electrons in the substrate and so preventing current from flowing through the transistor. Since the gate retains its charge indefinitely (for many years at least), it is called a *floating gate*.

An EPROM is virtually a permanent data store for it is likely that the equipment itself will become obsolete before the charges leak away from the capacitors. But there may be a need to revise the data, perhaps to improve the performance of the equipment, in which event the EPROM can be erased and reprogrammed. Erasing requires the charge to be removed from the gate. This is done by exposing the chip to ultraviolet (UV) radiation for a period of about 30 minutes. To allow for this, the package of an EPROM has a quartz window just above the chip. Irradiation with UV light provides the electrons with extra energy which allows them to escape from the gate. The ease with which EPROMs may be reprogrammed repeatedly makes them ideal for developmental work.

Another type of reprogrammable ROM is the *electrically erasable programmable* ROM, or EEPROM. This has a similar structure to that in Fig. 43, but with a second gate, known as the *control gate*, on the upper surface of the silicon dioxide, just above the floating gate. The control gate is elec-

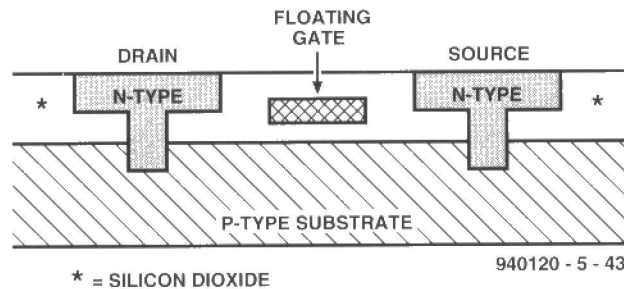


Fig. 43

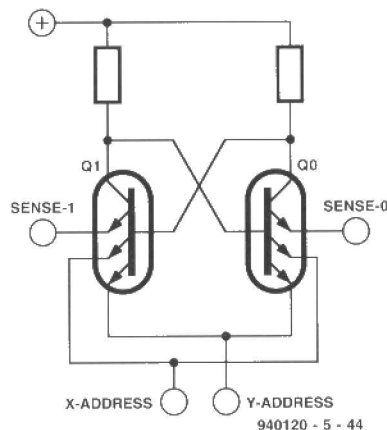


Fig. 44

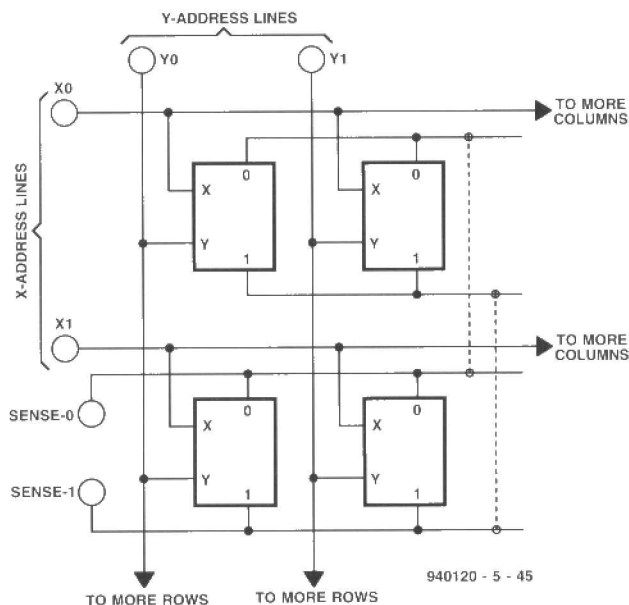


Fig. 45

trically connected to erasing circuits. The EEPROM is programmed in the same way as an EPROM, but the erasing technique is different. A positive voltage is applied briefly to the control gate, causing electrons in the floating gate to tunnel their way through the silicon dioxide, and so discharging the floating gate. This restores the bit stored in that cell to 1. If required, the

whole chip can be erased in one operation and all the data stored converted to 1s, or bits can be changed individually. Erasing a whole chip takes about 20 ms, a much quicker process than irradiating with UV light. EEPROMs have applications similar to those of EPROMs and, since they are more quickly reprogrammed, it is feasible to use them as non-volatile read/write memory, as

we shall describe later.

Read/write memory

The most commonly used name for this type of memory is *random access memory*, otherwise known as RAM. This is an unfortunate name for two reasons. One is that the word 'random' implies (to a statistician at least) that access to the memory locations is a haphazard affair, which it most certainly is not. Secondly, if we accept that 'random access' means that we can access any memory location we choose at any time (as opposed to having to read them or write to them in numerical order of address), the same description applies equally to ROM. Both types of memory have (so-called) random access, but the description is conventionally applied to only one of them.

Figure 44 shows the circuitry present at each cell of a typical RAM. It has a layout similar to that of the bistable in Fig. 39, which is to be expected, because a bistable is easily written to and read from. When the bistable is storing a 0, Q_0 is on and Q_1 is off. When it is storing a 1, Q_0 is off and Q_1 is on. The transistors in this bistable are unusual in having three emitters. Two of these are connected to address lines X and Y. When a cell is not being addressed, either X or Y or both are low and current passing through the 'on' transistors flows into X, or Y, or both. No current flows out through the sense-0 or sense-1 lines. Thus, the cell is effectively inactive. A cell is addressed by making both its X-address and Y-address inputs high. This prevents current from flowing to the address lines. Instead, it flows out through one of the sense lines. Which line it flows through depends on which transistor is on. If Q_1 is on, current flows into the sense-1 line, but no current flows to the sense-0 line because Q_0 is off. In summary, to read from a cell, apply a high voltage to both its X and Y address lines, and monitor its sense-0 and sense-1 outputs. Note that reading the contents of a cell does not alter its contents; the state of the bistable is unchanged. We say that readout is *non-destructive*.

When a cell is to be written to, its address lines are both made high, as above. A transistor which is on can be turned off simply by making its sense line high so that no current can flow out of any of its emitters. The sense line of the other transistor must be made low, allowing it to be turned on as the bistable changes state.

Figure 45 shows how four such cells are addressed individually. There are two X-address lines, corresponding to the rows of cells, and two Y-address lines corresponding to the columns of cells. To address the lower cell in the left column, we make $X_0 = 0$, $X_1 = 1$, $Y_0 = 1$ and $Y_1 = 0$. The sense-0 connections of all cells are made to a common sense-0 line. There is also a common sense-1 line. Only one cell is active at any one time so its state can be read by monitoring the current on the two sense lines. To write a 0 to a given cell, we make the sense-0 line high and the sense-1 line low, then address the cell. To write a 1, we make sense-0 low and sense-1 high, then address the cell.

RAM chips employing bipolar junction transistors have a short access time: of the order of 25 ns. Those based on similar operating principles, but using NMOS technology, have a much longer access time: usually 200–400 ns. This is no disadvantage in many applications. The big advantage of NMOS chips is that the transistors are much smaller than BJT types, so many more can be packed on to a single chip. Memories storing over a million bits, that is, over 130 kilobytes, are commonly available and are inexpensive. The newer CMOS high-speed RAMs have access time averaging 30–50 ns and are replacing BJT RAMs in most applications.

It is possible to have the best of both worlds with a non-volatile RAM that comprises a RAM and an EEPROM on the same chip. Their addressing is such that each bit in the RAM is activated at the same time as the corresponding bit in the EEPROM. Reading from and writing to the RAM is fast and, at any instant, the contents of the RAM can be copied into the EEPROM at high speed. Once

in the EEPROM, the data is non-volatile and is retained when the power is switched off. When the power is switched on again, data in the EEPROM is copied back into the RAM.

Dynamic RAM

The RAM we have described so far is known as *static* RAM. Once the flip-flop has been put into a given state, 0 or 1, it remains in that state until its state is changed by writing new data into it, or until the power is switched off. By contrast, there is a type of RAM known as *dynamic* RAM. The word 'dynamic' suggests movement and change. The reason for this name is best understood by looking at the structure of a single cell (Fig. 46). The cell consists solely of a MOSFET and a capacitor. The MOSFET acts as a *transmission gate*, which is the equivalent of a switch. When the address line is made high, the transistor is turned on and current is able to flow in either direction through it. When the address line is low, there is virtually no conduction through the transistor and the capacitor is isolated. To write data to the cell, the address line is made high and the data is made high or low, depending on whether a 1 or a 0 is to be stored. Current flows through the transistor, either charging or discharging the capacitor. The address line is then made low again and the capacitor retains its charge. To read from the cell, the address line is made high. If a 1 is stored there, some of the charge on the capacitor flows through the data line, is amplified and registered as a logic 1. But the act of reading removes some of the charge; we say that the read-out is *destructive*. As a consequence of this, the memory must be *refreshed*, topping up the charge on each charged capacitor. This is done automatically by reading the stored data at regular intervals and immediately storing the same data back into each cell. This can be done on a row-by-row basis to save time and needs to be done every few milliseconds. The *refresh cycle* is part of the operating sequence of a modern computer. *Dynamic memory control* ICs are used to

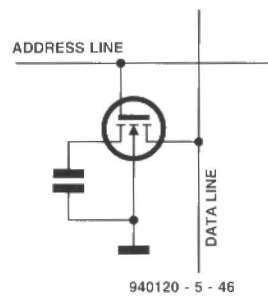


Fig. 46

perform this task, or the control units may be built into the dynamic memory IC. The need to refresh this type of RAM makes the timing of the computer's processing more complicated and more critical. No other memory operations can take place while the RAM is being refreshed, so the rate of operation of the computer is reduced. But the cell of the dynamic RAM is so small that millions of cells can be accommodated on a single chip: an advantage that outweighs the disadvantages. Dynamic RAM chips with 4 or 16 megabytes capacity are commonplace and are more widely used nowadays than static RAMs.

Storage and usage

Those who are unfamiliar with the ways of the computer may wonder why it is so important to be able to store vast quantities of data in such a hurry. If studying a screenful of data or printing out a table of data takes several minutes, it would seem that whether RAM is stored or read by the computer in nanoseconds, microseconds or even milliseconds is quite immaterial. The key to the situation is that RAM is a bottleneck, and one reason for this is that storing a

bit in RAM costs around 1000 times as much as storing it on a magnetic disk, so we keep RAM to a minimum. In addition, RAM requires power, it generates heat which has to be got rid of if the circuits are to function properly and it takes up an appreciable area of the computer mother board. Therefore, we store as much data as possible in peripheral storage (for example, magnetic disk) and use RAM only for the currently important activities. At the beginning of a computing session, RAM is loaded with the main program and the subsidiary programs needed to support it, since these programs can be run only when they are in RAM. The remainder of the RAM is available for data that the programs might need and for any data generated by the program itself. Usually, RAM is not big enough to hold the whole program or all the data. The frequent whirring of disk drives indicates that the computer is continually loading data from disk to RAM and storing data from RAM to disk as the program proceeds from stage to stage. Unless data can be transferred between RAM and disk at high speed, the overall operation of the computer is slowed down. This is why access times need to be reckoned in nanoseconds.

[940120-V]

Test yourself 5

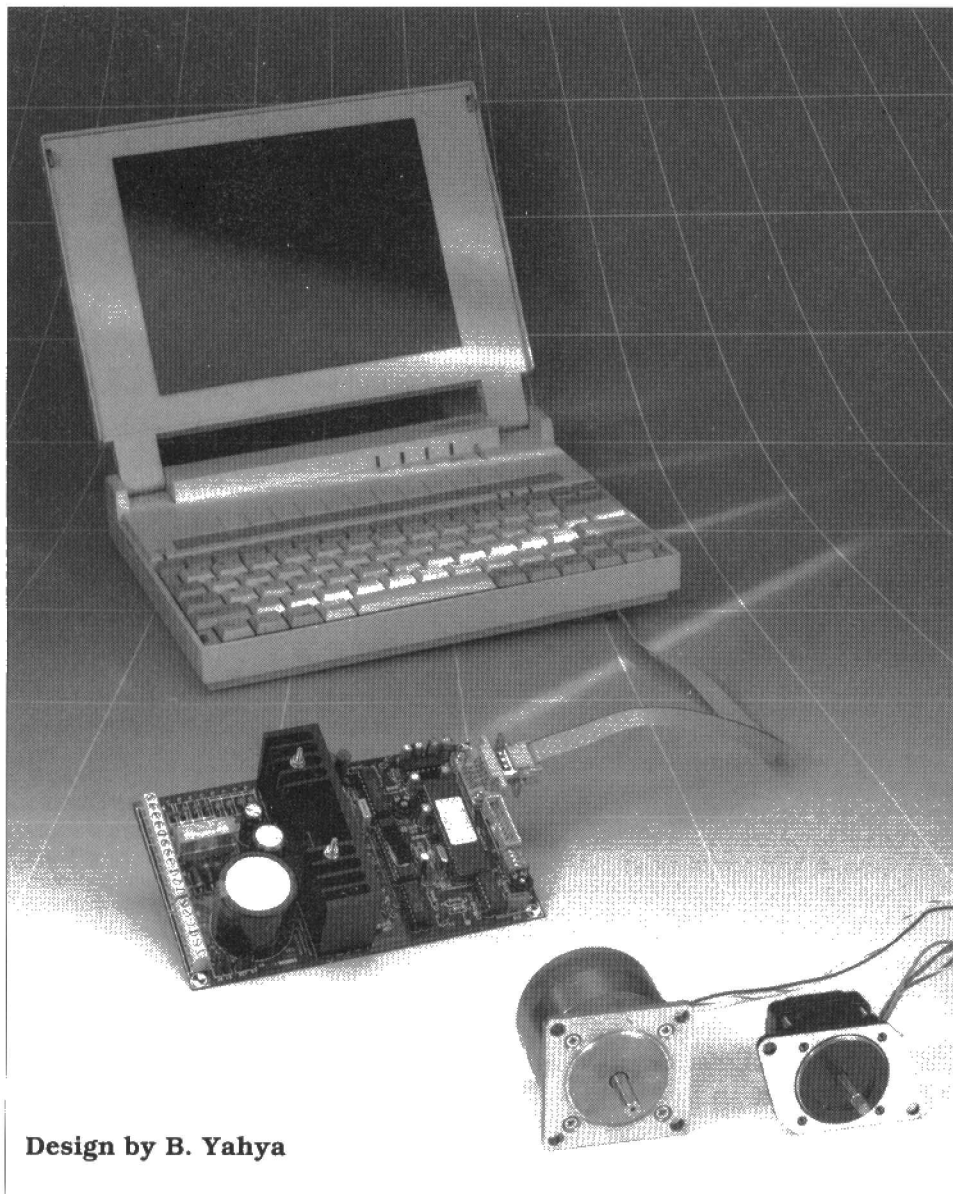
1. What data is stored in nybble 2 in Fig. 40?
2. Design an address decoder for the ROM of Fig. 40, in which none of the address lines are made high when the input is 11.

Answers to Test Yourself 4

- | 1. Control output | DAC output (V) | Comparator output |
|-------------------|----------------|---------------------------------|
| 00000000 | 0.00 | high |
| 10000000 | 1.28 | low |
| 01000000 | 0.64 | high |
| 00100000 | 0.32 | low |
| 00110000 | 0.48 | high |
| 00101000 | 0.40 | low |
| 00101100 | 0.44 | low |
| 00101110 | 0.46 | high |
| 00101101 | 0.45 | correct, retain present setting |
| 00101101 | 0.45 | correct, conversion complete |
2. $U_{in} = -(-5 \times 250/400) = 3.125$ V (R , C and clock rate do not enter into the calculation).
 3. 15 comparators; 0.3125 V

STEPPER MOTOR CONTROL

Many PC users use their computer to control electromechanical systems. In these applications, it is often required to switch and control stepper motors. The circuit presented here communicates with the PC via the serial (RS232) interface, and is capable of driving two stepper motors. One of these does half steps only, the other, half or full steps. The control board is a truly multi-purpose design which is suitable for a wide variety of electromechanical applications based on stepper motors.



Design by B. Yahya

STEPPER motors are ideal companions for many electromechanical control applications. The spindle of a stepper motor rotates by an accurately defined amount whenever a clock pulse is fed to the controller.

Depending on the mode in which the motor operates, a full turn of the spindle is usually divided into 100 or 200 steps, hence the name stepper motor. Provided the design of the controller is right, the relative position of

the spindle is always known.

With an ordinary d.c. motor, extra things are required to determine the position of the spindle. Stepper motors have another important advantage: torque is established as soon as the motor is actuated. Consequently, the spindle may be loaded at any time, and irrespective of its speed. By comparison, a d.c. motor must run at a certain minimum speed to develop torque on the spindle. Of course, stepper motors also have disadvantages. While a normal d.c. motor can be switched on and off by a simple relay, a stepper motor always requires a dedicated controller for the same function.

The multi-purpose control presented in this article solves the problems associated with driving a stepper motor in a simple manner. It enables any PC or compatible to take control of a stepper motor with the aid of a set of simple commands, via the serial interface.

The card contains the complete control logic for two motors: a main motor and an auxiliary motor. The main motor may be operated in half-step or full-step mode. The auxiliary motor operates in half-step mode only. In addition to two stepper motor drivers, the card also contains eight digital inputs and five digital outputs, whose current level can be interrogated and changed directly by the computer. These I/O lines are very useful for additional control functions.

Because the interface on the stepper motor card communicates via a standard RS232 or RS485 link, it can be used with almost any PC or micro-controller system.

Serial interface

Figure 1 shows the complete circuit diagram of the stepper motor control. Despite its wide range of options, the circuit is reasonably simple and compact. As already mentioned, communication is via a standard RS232 interface. Here, the interface is designed such that it may also be used with RS485 ports. If this option is used, up to 16 of these stepper motor controllers may be connected in parallel to the computer's serial port. The RS232/RS485 connection on the motor interface (K₂) is realized by a standard 9-way sub-D socket. A key function in the interface is performed by IC₃, a single-voltage RS232 line driver/receiver type MAX232 from Maxim, Inc. This driver IC has on-board voltage step-up converters

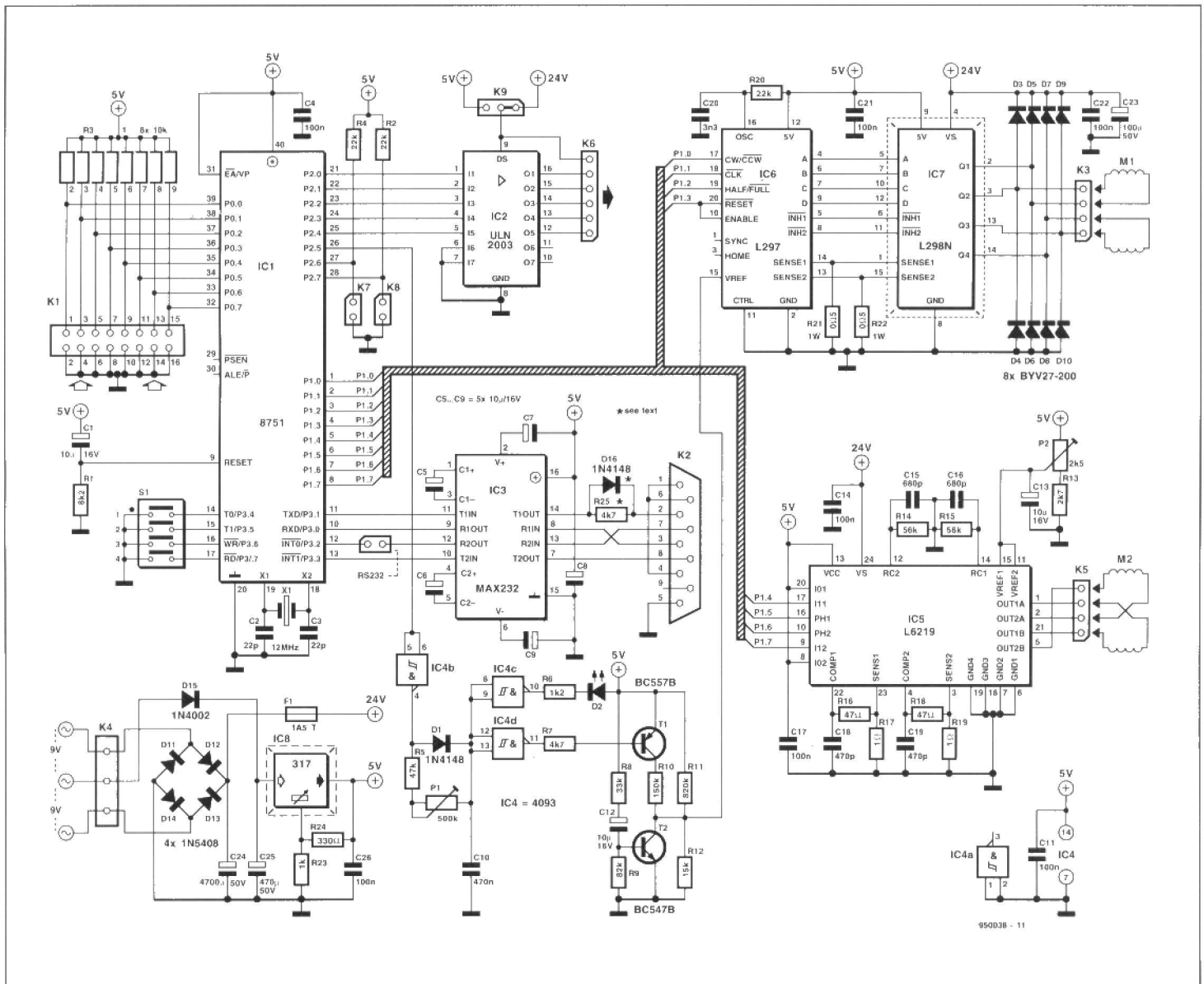


Fig. 1. Circuit diagram of the intelligent stepper motor control. At the heart of the circuit is a pre-programmed microcontroller type 87C51.

based on charge pumps which furnish the positive and negative RS232 line voltages (approx. 10 V). The IC also buffers the TxD and RxD signals of the microcontroller in the circuit, IC₁, as well as two handshaking signals, RTS and CTS.

The TxD (transmit data) line contains a resistor, R₂₅, and a diode, D₁₆. These components are only required if the RS485 interface is used. If you require just the RS232 interface, R₂₅ may be replaced by a wire link. If the card is connected to an RS485 system, resistor R₂₅ may be present on one card only. On all other cards, it must be omitted (i.e., removed or not fitted, NOT replaced by a wire link!).

The configuration of the RS485 system is shown in Fig. 2. The address of the interface, 0 through 15, is pre-set with the aid of DIL switch S₁. If you use only one card, S₁ may be omitted, so that address 0 is used to communicate with the card.

The protocol

The structure of the communication protocol designed for the stepper motor control is straightforward and, therefore, very flexible in everyday use. The computer sends an instruction to the interface, which responds by per-

forming it. In case the interface is still working on a previous instruction, the computer receives a status word which has bit 7 at logic '1'. The computer recognizes this as an 'interface busy' signal, and keeps sending the current instruction until a status word is received whose bit 7 is at '0'. This may

MAIN TECHNICAL DATA

Number of motors:	2
Modes:	half-step and full-step
steps/s:	30 to 1,000
Motor 1:	biphase, max. 750 mA per winding
Motor 2:	biphase, max. 2 A per winding
Digital inputs:	8 (TTL)
Outputs:	5 (5V or 24V, max. 500 mA)
Interface:	RS232 or RS485
Available card addresses:	16
Serial data format:	2400 baud, no parity, 8 databits, 1 stop bit

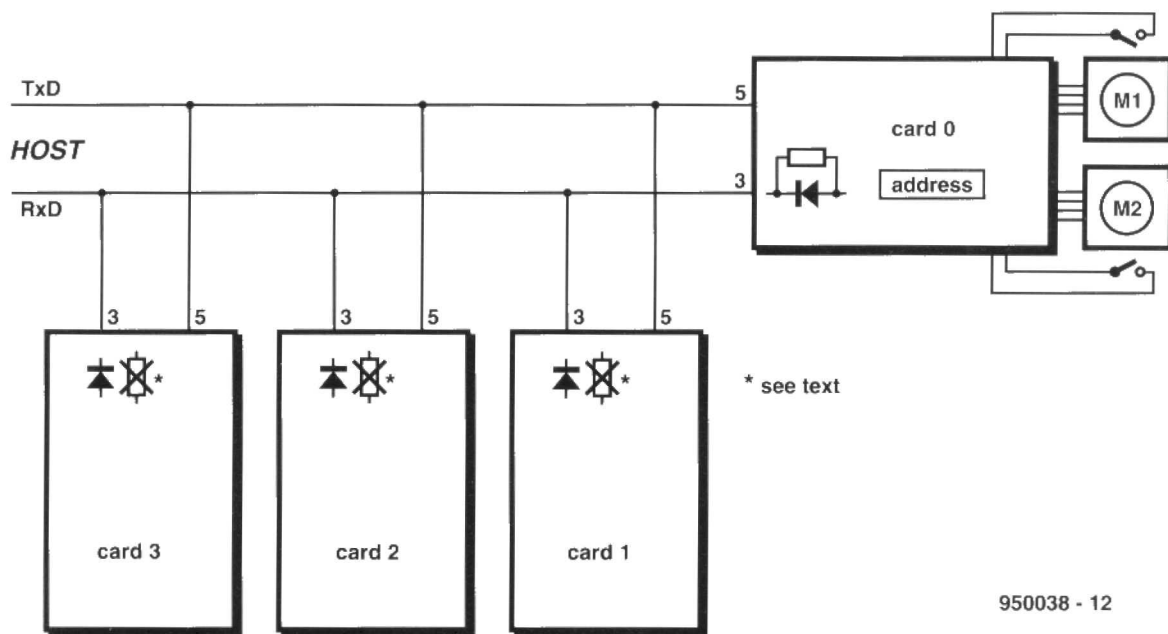


Fig. 2. Showing how up to 16 stepper motor controls may be connected to an RS485 interface.

look fairly complex, but the aim is to enable several parallel connected interfaces to be used. The simple protocol thus prevents any one of the interfaces from putting data on to the serial bus at an arbitrary moment, thereby corrupting the communication between the PC and another interface. An interface should return the status word within 10 ms after receipt of an instruction. If this does not happen, something is wrong.

Switching currents

All of the intelligence offered by the control is vested in IC₁, a pre-programmed microcontroller type 87C51. The two stepper motor controllers are connected to port P1, while port P3 communicates with the serial interface and the interface address encoding circuit. The interface address can be set to a value between 0 and 15 with the aid of DIP switch S₁. The address is

read from the switch after each system reset, and stored in the internal RAM memory.

The small motor is powered by an L6219 stepper motor driver IC from SGS-Thomson Microelectronics. This driver uses pulsewidth modulation to control the current through the two stator windings. The current is adjusted with the aid of preset P₂. Two RC networks, R₁₅-C₁₅ and R₁₆-C₁₆, determine the off-time of the upper tran-

L6219, a compact controller

The L6219 is a bipolar monolithic integrated circuit intended to control and drive both windings a bipolar stepper motor, or bidirectionally control two d.c. motors.

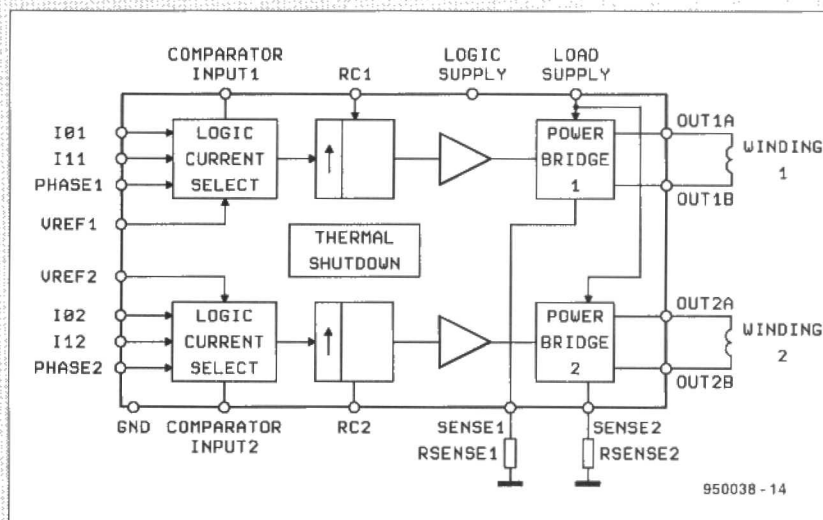
The L6219 with a few external components forms a complete control and drive circuit for LS-TTL or a microprocessor controlled stepper motor system. The power stage is a dual full-bridge capable of sustaining 50 V, and includes four diodes for current recirculation.

A cross-conduction protection is provided to avoid simultaneous cross conduction when the switching current is reversed.

An internal pulse-width modulation (PWM) circuit controls the output current to a maximum nominal value of 750 mA, with a peak start current of up to 1 A.

The nominal motor winding current is set for each bridge individually by a reference voltage, while a number of logic inputs control the motor direction and mode of operation (half-step, full-step or micro-step).

A thermal protection circuit disables the outputs if the chip temperature exceeds safe operating limits.



sistors in the internal bridge circuit. Pins 23 and 3 of the L6219 are connected to sensor resistors R_{17} and R_{19} . These resistors measure the current through the stator windings. RC filters R_{16} - C_{18} and R_{18} - C_{19} filter the voltages developed by these resistors before a comparator compares the voltages with a reference level.

The main motor is controlled by two ICs, also from SGS-Thomson: an L297 and an L298. The former generates the pulses for the motor control, while the L298 contains a bridge driver which forms the actual interface with the motors. The basic operation of these ICs is discussed briefly in an inset.

The V_{REF} input of IC₆ is connected to a fairly complex circuit, which reduces the current through the stator windings during the 'off' periods. This is done under software control. The voltage at the V_{REF} input is compared with the voltage dropped by R_{21} and R_{22} . If the voltage across these resistors exceeds the reference level, the motor current is interrupted. In this way, the current through the stator winding is held at a predefined limit.

At power-on, the V_{REF} input of IC₆ is pulled to ground via transistor T_2 . Consequently, no current is allowed to flow through the motor's stator winding. After the reset period, V_{REF} is held at a voltage which is supplied by a voltage divider consisting of R_{11} and R_{12} . This guarantees a minimum hold current. As soon as the motor has to run, the input of IC_{4b} is pulled low. Consequently, capacitor C_{10} is charged via diode D_1 , and the outputs of IC_{4c} and IC_{4d} drop low. LED D_1 lights, and T_1 starts to conduct, so that R_{10} is connected in parallel with R_{11} , and V_{REF} is effectively raised. From then on, current is allowed to flow through the motor winding again. A few milliseconds after the motor is instructed to do a step, the system may switch back to standby current. The number of milliseconds depends on the inertia of the stepper motor used. Hence, this time can be adjusted with a preset, P_1 .

Two inputs on the processor are reserved for the end switches, which should be normally closed (n.c.) types. K_7 should be opened when motor M_1 is in the zero position. When K_8 is opened, the software assumes that motor M_2 has arrived at its zero position. In this way, the spindle position can be made to correspond with the position recorded by the software. This reference position has to be found any time the system is reset. A special instruction is reserved in the software for this function.

The P2 lines of the microcontroller are connected to a type ULN2003 buffer/driver whose outputs are capable of driving relays with a coil voltage of 5 V or 24 V. The load should be con-

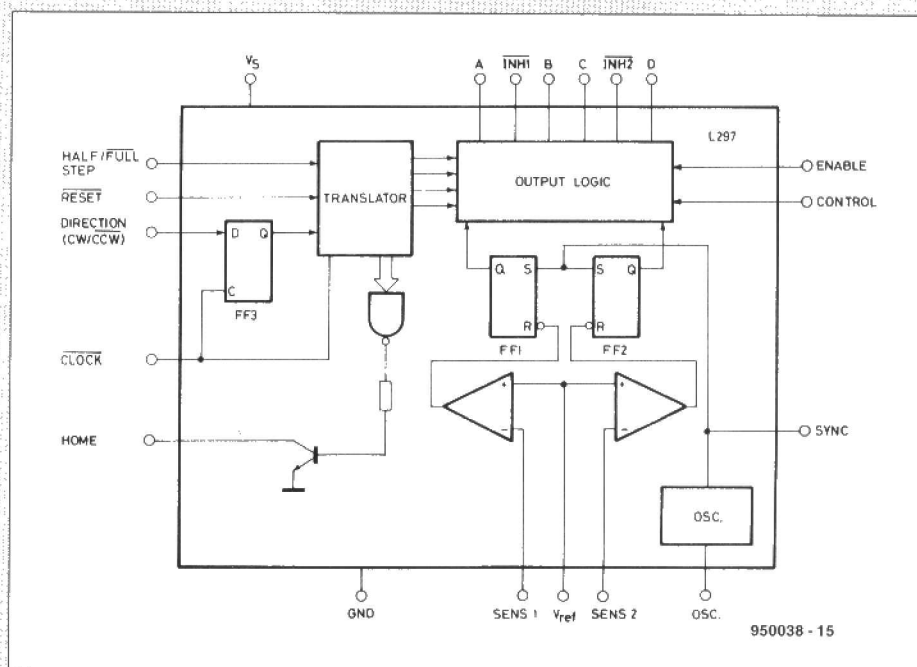
nected between the first connection of K_6 , and the desired output of IC₂. The voltage level (5 V or 24 V) is selected with the aid of wire link K_9 .

The microcontroller operates in a standard configuration with the clock

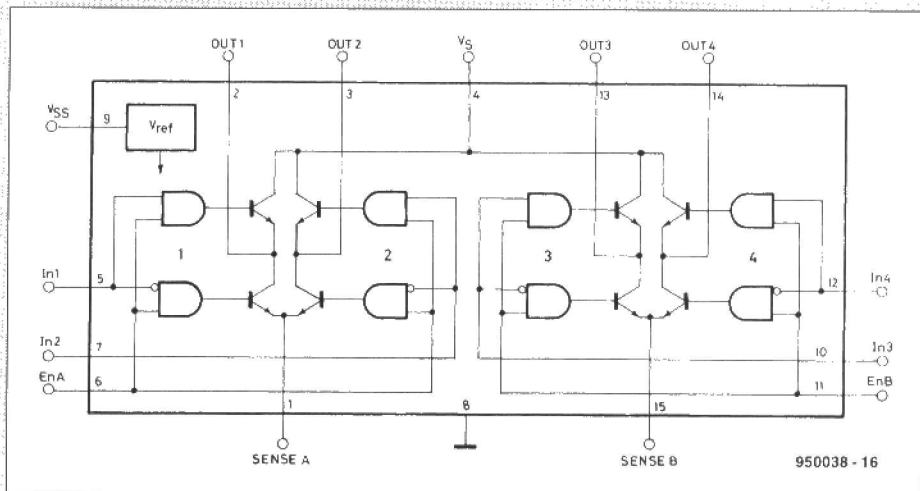
oscillator running at 12 MHz. The reset signal is automatically furnished by C_1 and R_1 when the card is switched on. The I/O lines of port P0 are fitted with pull-up resistors from a SIL array. Because these inputs have

L297 and L298: a powerful pair

The auxiliary motor is controlled by a combination circuit consisting of an L297 and an L298N, both from SGS-Thomson. The L297 is the controller, while the L298N contains the power driver section in the form of a double bridge circuit. The latter IC controls the current through the stator winding by means of pulse-width modulation. The L297 has a clock input and two control inputs to select the motor direction, and switch the mode of operation between half-step and full-step.



The L298 is a double bridge used in combination with, for instance, the L297. The bridge is capable of supplying a nominal current of 2 A, and peak currents of up to 3 A, at a maximum supply voltage of 36 V. The stator current which flows through the bridge causes a voltage drop across the sense resistors connected to the common emitter terminals of the lower transistors in the bridge. These terminals are bonded out to pins 1 and 15. The L297 compares the voltage across the sense resistors with the reference voltage at its pin 15. Increasing or decreasing the reference voltage therefore affects the nominal value of the stator current.



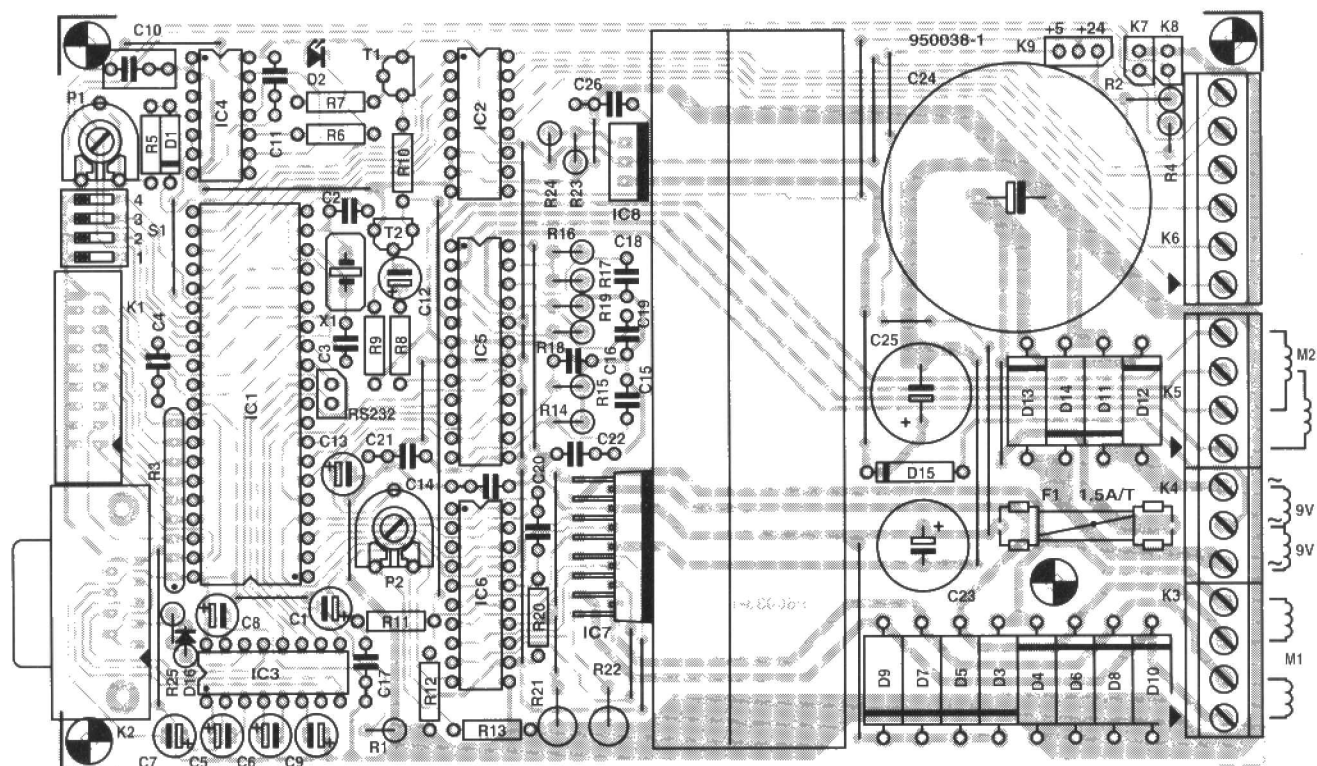
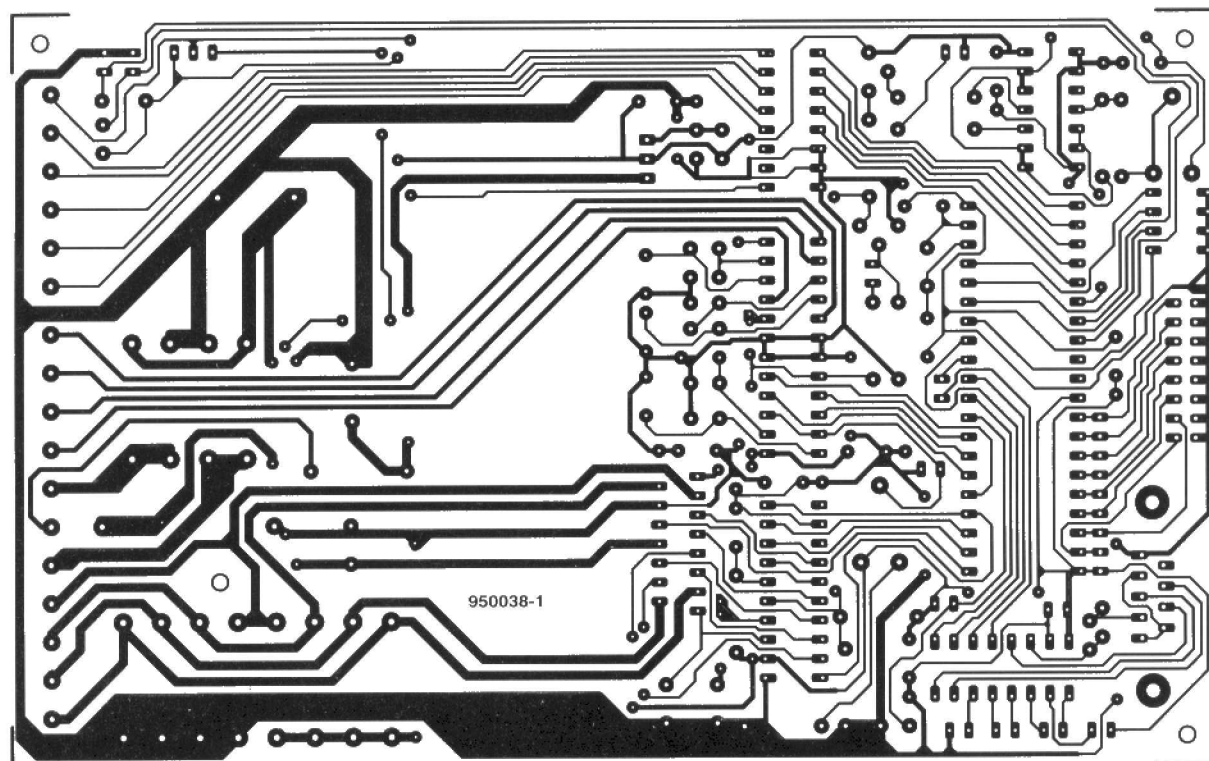


Fig. 3. Track layout and component mounting plan of the single-sided printed circuit board designed for the stepper motor control (board available ready-made through the Readers Services, see page 70).

COMPONENTS LIST

Resistors:

$R_1 = 8k\Omega$
 $R_2, R_4, R_{20} = 22k\Omega$
 $R_3 = \text{SIL resistor array } 8 \times 10k\Omega$
 $R_5 = 47k\Omega$
 $R_6 = 1k\Omega$
 $R_7, R_{25} = 4k\Omega$
 $R_8 = 33k\Omega$
 $R_9 = 82k\Omega$
 $R_{10} = 150k\Omega$
 $R_{11} = 820k\Omega$
 $R_{12} = 15k\Omega$
 $R_{13} = 2k\Omega$
 $R_{14}, R_{15} = 56k\Omega$
 $R_{16}, R_{18} = 47\Omega$
 $R_{17}, R_{19} = 1\Omega$
 $R_{21}, R_{22} = 0\Omega$ 5 W
 $R_{23} = 1k\Omega$
 $R_{24} = 330\Omega$
 $P_1 = 500k\Omega$ preset H
 $P_2 = 2k\Omega$ 5 W preset H

Capacitors:

$C_1, C_5, C_9, C_{12}, C_{13} = 10\mu\text{F } 16\text{V radial}$
 $C_2, C_3 = 22\text{pF}$

$C_4, C_{11}, C_{14}, C_{17}, C_{21}, C_{22}, C_{26} = 100\text{nF}$
 $C_{10} = 470\text{nF}$
 $C_{15}, C_{16} = 680\text{pF}$
 $C_{18}, C_{19} = 470\text{pF}$
 $C_{20} = 3\text{nF}$
 $C_{23} = 100\mu\text{F } 50\text{V radial}$
 $C_{24} = 4700\mu\text{F } 50\text{V radial}$
 $C_{25} = 470\mu\text{F } 50\text{V radial}$

Semiconductors:

$D_1, D_{16} = 1\text{N4148}$
 $D_2 = \text{LED } 3\text{mm}$
 $D_3, D_{10} = \text{BYV27-200}$
 $D_{11}, D_{14} = 1\text{N5408}$
 $D_{15} = 1\text{N4002}$
 $T_1 = \text{BC557B}$
 $T_2 = \text{BC547B}$
 $\text{IC}_1 = 8751$ (order code 956503-1)
 $\text{IC}_2 = \text{ULN2003}$
 $\text{IC}_3 = \text{MAX232}$ (Maxim)
 $\text{IC}_4 = 4093$
 $\text{IC}_5 = \text{L6219}$ (SGS-Thomson)
 $\text{IC}_6 = \text{L297}$ (SGS-Thomson)
 $\text{IC}_7 = \text{L298N}$ (SGS-Thomson)
 $\text{IC}_8 = \text{LM317}$

Miscellaneous:

$K_7, K_8, K_9, \text{RS232} = \text{pin header with jumper. } (K_9 = 3\text{-way}).$
 $K_1 = 16\text{-way boxheader.}$
 $K_2 = \text{DB9 sub-D socket, PCB mount.}$
 $K_3, K_5 = 4\text{-way PCB terminal block, pitch } 5\text{mm.}$
 $K_4 = 3\text{-way PCB terminal block, } 5\text{mm.}$
 $K_6 = 6\text{-way PCB terminal block, } 5\text{mm.}$
 $S_1 = 4\text{-way DIP-switch.}$
 $X_1 = \text{crystal } 12\text{ MHz.}$
 $F_1 = \text{fuse } 1.5\text{ AT.}$
 1 heatsink (Fischer* SK401, SK19 or SK28, height = 37.5mm).
 1 Glue-on heatsink for L6219.
 Printed circuit board, programmed 8751 (IC₁) and test program on disk: order code 950038-C (see page 70).
 Programmed 8751 (separate): order code 956503-1 (see page 70).
 Floppy disk (separate): order code 956004-2 (see page 70).

* Dau Components, tel. (01243) 555031, fax (01243) 553860.

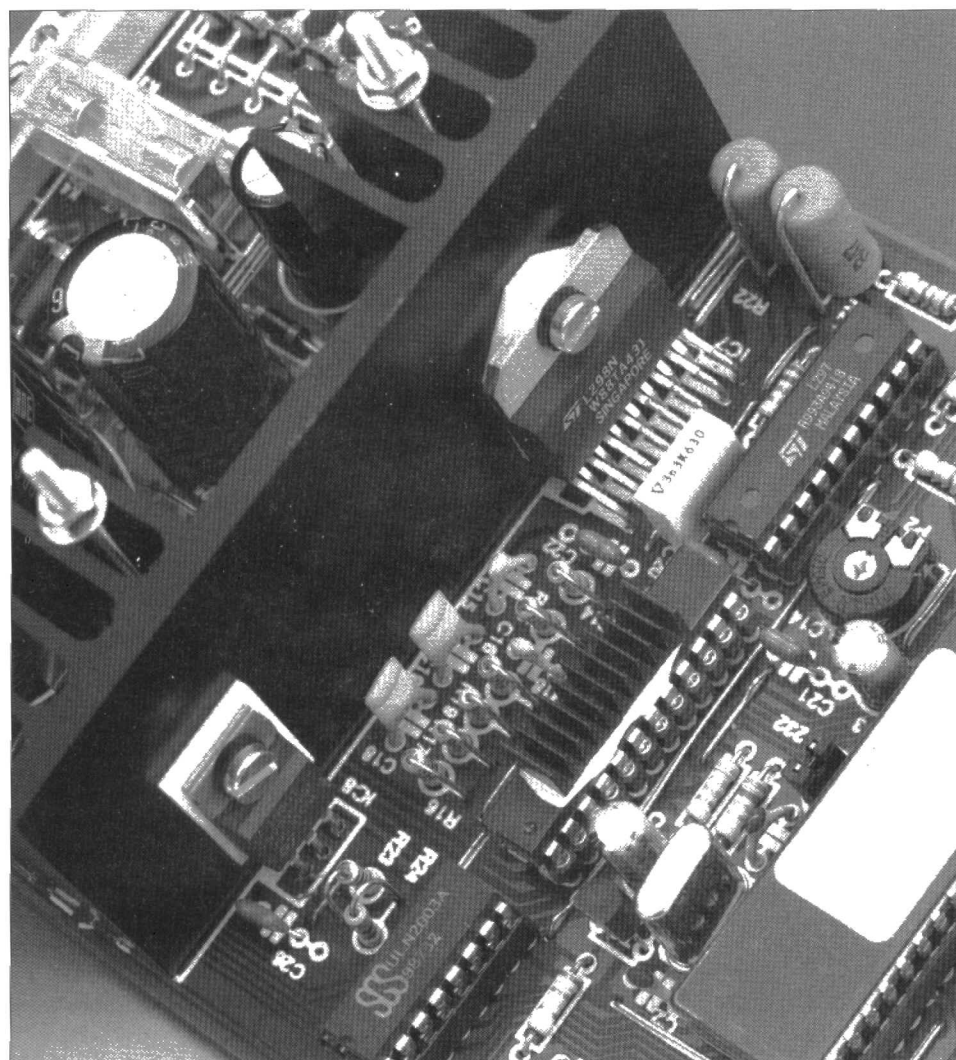


Fig. 4. A close look at the two ICs mounted on the heat-sink.

no external protection, the voltages applied to them must have TTL level. Higher voltages may damage the controller.

The supply voltage for the stepper motors is supplied by a transformer connected to terminal block K_4 . Here, it is assumed that the motor voltage is 24 V. The transformer is protected by a fuse rated at 1.5 A. When larger motors are used (which obviously calls for a larger transformer) the fuse rating may be changed to a maximum of 5 A.

The 5-V supply voltage is obtained from double-phase rectification of the centre tap of the transformer used. The voltage regulator, an LM317, is set to supply an output voltage of 5 V with the aid of resistors R_{23} and R_{24} .

Construction

The circuit is not difficult to build on the Eurocard sized printed circuit board shown in Fig. 3. The component placement allows the board to be fitted vertically into a 19-inch rack. This type of housing will be particularly useful if a system comprises of several stepper motor cards.

Start the construction by drilling two 3-mm dia. holes in the board to enable the heat-sink to be secured. Stay clear of PCB tracks! The photograph in Fig. 4 illustrates the mounting of the heat-sink with the aid of two long M3 (6BA) bolts. The location of the holes in the PCB is determined by the ribs of the heat-sink. Next, drill

Control signal structure

STX	Address	Command no.	Data (optional)	ETX
-----	---------	-------------	-----------------	-----

STX: 02H, start marker
 ETX: 03H, end marker
 Address: 30H to 3FH
 Command no.: number from command set, where bit 7 = 1
 Data: ASCII numbers, negative sign (-) allowed
 All data returned by the card is all-binary code.

Example

To make motor M1 do -350 steps from the current position, the following sequence is sent to the card (card address = 5):

hexadecimal data:	02	35	83	2D	33	35	30	03
	STX	address '5'	command OR 80H	ASCII '-'	ASCII '3'	ASCII '5'	ASCII '0'	ETX

all data consists of integers in the range -6000 to +6000

Structure of the status byte returned by the card

bit no.	function
7	Bit at '1' means the card is busy executing a command. The previously sent command is not (yet) executed.
6	Bit at '1' means motor M1 initialized (zero positioning command completed)
5	Bit at '1' means motor M2 initialized (zero positioning command completed)
4	Bit at '1' means motor M1 switched to half-step mode, '0' means motor M1 switched to full-step mode.
3,2,1,0	Card address returned via these bits in response to certain commands. With all other commands, they are at '0'.

Serial channel settings: 2400 baud, no parity, 8 databits, 1 stop bit

Interpretation of acceleration and deceleration (braking) data

With motor M1, commands to move the spindle to a certain position are always executed according to a fixed pattern. The motor starts with an initial speed, and then performs a number of acceleration steps until it reaches the nominal speed. Braking means that the motor's nominal speed is slowly decreased according to the programmed number of deceleration steps, until the stop speed is reached.

The acceleration and deceleration stages consist of a number of units which can be programmed between 10 and 250. Using this data (start and stop speed, nominal rotational speed and the number of acceleration and deceleration steps) the card computes the way the motor is to be driven. If these parameters are not supplied by the user, internally fixed default values are used.

two 2.5-mm dia. holes in the flat side of the heat-sink, and use an M3 tap to thread these holes. They are necessary for the mounting of IC₇ (L298N) and IC₈ (LM317). The M3 screws used to secure these devices on to the heat-sink are electrically isolated from the metal tabs with the aid of a plastic bush and a mica or ceramic washer.

Next, fit the wire links on the board. Then follow the connectors and IC sockets, and the other components. To save board space, many resistors are mounted upright. Pay attention to the polarity of the diodes and electrolytic capacitors.

The L6219 dissipates a fair amount of heat, and therefore requires a small DIL heat-sink which can be glued or clamped on the IC case.

The RS232 interface is designed

such that crossed wires are not necessary in the connecting cable. The 9-way link should be pin-for-pin, and is easy to make yourself from a length of 9-way flatcable with an IDC-style sub-D connector pressed on at either end.

Set P₁ to the centre of its travel, and then connect the card to the PC and to the mains. Switch on the PC. Nothing should happen, except, possibly, for a squeaking noise from one of the stepper motors, caused by the hold current.

The control software

As already mentioned, the software which belongs with this project is contained in the 87C51 microcontroller on the stepper motor card. This controller is supplied to you ready-programmed

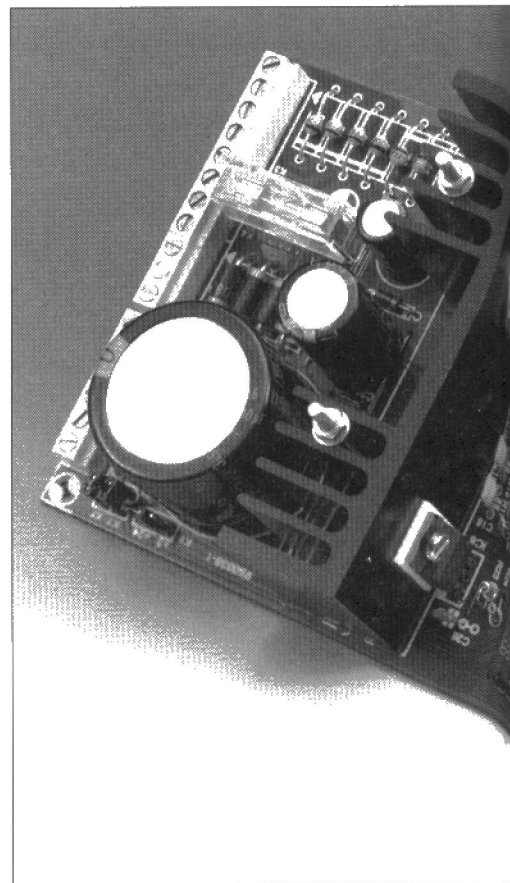


Fig. 5. Finished and tested prototype of the capable of driving two stepper motors under

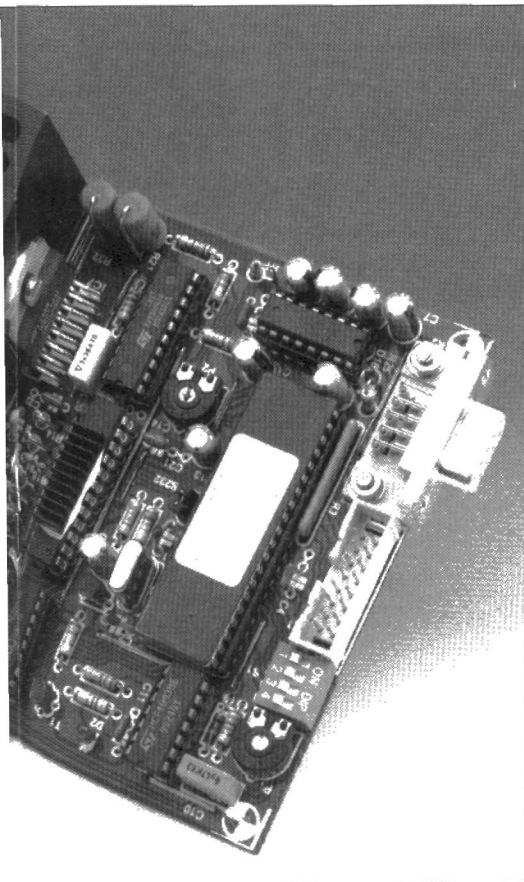
through the Readers Services, together with the PCB and a diskette, or as a separate item. The software enables the PC to control the motors with the aid of simple instructions. The complete instruction set is given in a separate inset.

The diskette supplied for this project contains a test program which enables you and your PC to check the operation of the stepper motor control. The program is started from the DOS prompt by typing

```
steptest -px
```

where x is the number of the COM port used. Parameter 'p1' therefore corresponds to COM1:. Valid numbers for x are 1, 2, 3 or 4. The default setting is COM2:.

After starting the program, the number and the I/O address of the selected COM port appears in the top right-hand corner of the screen. The screen offers nine options to test the card, with the prompt 'select an option' at the bottom. If something is wrong with the communication between the card and the computer, this prompt is replaced by 'Q-C-I', which allows you to Q(uit), C(ontinue) or (T)est. Any time the 'T' key is pressed, the software attempts to communicate with the step-



stepper motor control. The board control board is computer control.

the corresponding output. The program then toggles the output levels continuously, causing all LEDs to flash.

Once the digital inputs and outputs are known to function properly, it is time to concentrate on the operation of the stepper motors. Connect them to the board. After switching on, they remain off, although they may produce a soft, squeaking noise because of the hold current sent through the windings. Next, fit two wire jumpers across connectors K₇ and K₈. After pressing key '8' or '9', the relevant motor will start to turn. As soon as the jumper is briefly removed, the motor stops at the (then) zero position (M₂), or end stop (M₁). The other menu options are then available. By pressing key '6' or '7' you define the current spindle position as the zero position. Menu option '1' then causes the motor to turn alternately clockwise and anti-clockwise (left/right) around this reference position. At the same time, the digital input levels are shown on the screen, while the outputs are switched in the same rhythm. With menu option '2',

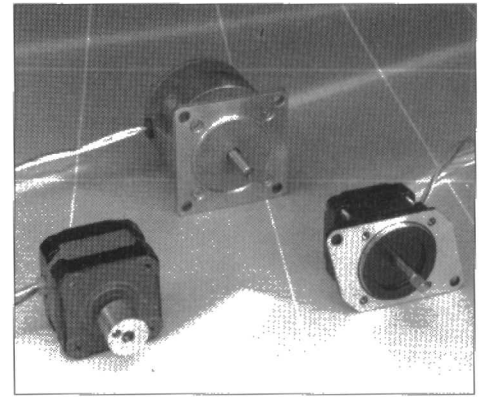


Fig. 7. A selection of biphas stepper motors which were used to test the prototype of the control.

motor M₂ instead of motor M₁ responds as described.

All test routines may be left by pressing the Escape (Esc) key. The program is left by pressing 'Q'.

If the test program operates successfully, it is safe to assume that the stepper motor control is fully functional. (950038)

per motor card. In this way, the serial link can be tested. To be able to use this test, the card address must be set to 0, i.e., all switches in S₁ must be opened.

Menu option '4' allows you to test the digital inputs of the card. Each change in the input level is displayed on the screen. Menu option '5' may be used to test the digital outputs. That can be achieved fairly simply by connecting an LED plus series resistor to

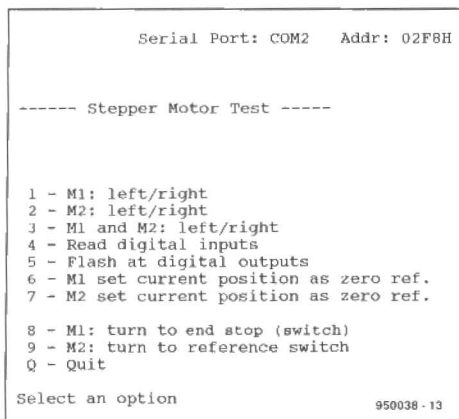


Fig. 6. The test program supplied on diskette allows you to run a quick but thorough test on the operation of the card.

Command set overview

Command (hex)	Data	Function
00	-	Turn Motor M1 to end stop (absolute zero ref.).
01	-	Emergency stop of motor M1. No deceleration used, some overshoot may occur. Use 'zero reference position' as next command.
02	-	Store current position of M1 as virtual zero reference, for use by other commands.
03	yes	M1 does programmed number of steps from current position. Positive and negative values allowed.
04	yes	M1 turns to programmed position from zero reference.
05	-	Prompt card to return a status byte.
06-09	-	No function.
0A	yes	Enter number of steps to compensate mechanical tolerance on M1. Defines the number of steps made by the motor when it reverses. Default value is 0. Values between 0 and 255 allowed.
0B	yes	Change card address from address set by hardware. Status byte reports new address in the lower four bits.
0C	-	Read card address contained in lower four bits.
0D	yes	Enter number of acceleration steps for M1. Values between 10 and 255 allowed.
0E	yes	Enter number of deceleration steps for M1. Values between 10 and 255 allowed.
0F	yes	Set reference speed of M1 in μ s.
10	yes	Set nominal speed of M1 in μ s.
11	yes	Set start speed of M1 in μ s.
12	yes	Set stop speed of M1 in μ s.
13	-	Store current position of M2 as virtual zero reference, for use by other commands.
14	-	Turn Motor M2 to zero reference position.
15-17	-	Do not use.
18	yes	Get current position of M1. Card responds by returning status byte, followed by two position bytes (MSB-LSB).
19	-	Switch M1 to full-step mode.
1A	-	Switch M2 to half-step mode.
1B	-	Read 8-bit digital port. Card responds by returning status byte, followed by a byte containing the port word.
1C	yes	Set levels on five output port lines. Only bits 0 through 4 are used.
1D	yes	M2 turns to programmed position from zero reference.
1E	yes	M2 does programmed number of steps from current position. Positive and negative values allowed.
1F	yes	Get current position of M2. Card responds by returning status byte, followed by two position bytes (MSB-LSB).
20	yes	Set nominal speed of M2 in μ s.

Card returns status byte after every command.

ELECTRONIC BAROMETER

Design by J. Rutgers

'To measure is to know' is applicable not only to electronics, but also to weather forecasting. Temperature, relative humidity and barometric pressure can be measured with domestic weather stations. Such stations usually contain a traditional barometer, the design of which has not changed for centuries. This article describes a modern electronic barometer.

Many homes have a three-instrument 'weather station', consisting of a thermometer, a relative humidity meter and a barometer. Of these, the barometer is the one used to see whether there is going to be a change of weather. This is because there is a clear relationship between ambient air pressure and weather conditions. An increase in pressure normally indicates good, clear weather, whereas a fall usually means cloudy, rainy weather.

The traditional barometer has a few operating inconveniences. It is, for instance, necessary to tap the glass which covers the scale to make the pointer move to its correct position. Because of the construction of the barometer, the pointer usually sticks to a (wrong) position owing to friction. The next step is setting the 'memory pointer' so that it covers the scale pointer. This enables a comparison to be made between the reading then and one a few hours, or a day, later. This comparison shows whether the barometric pressure is falling, steady or rising.

The electronic barometer described in this article performs these actions automatically. The air pressure is indicated by one of a number of LEDs, and the change, if any, is shown separately by one of three

further LEDs.

Principle

In the block diagram of **Fig. 1**, the pressure sensor at the input converts the ambient air pressure into a direct voltage, which is applied to an amplifier. The value of the direct voltage is directly proportional to the air pressure.

The output of the amplifier is used to drive one of ten LEDs: the level determines which one. The ambient air pressure is read on the scale adjacent to the (lit) LED. Each of the ten diodes represents a step of 10 mbar.

The amplifier output is also applied to a window discriminator. The output determines which of the associated LEDs at the discriminator output lights; for example, if it rises, the LED opposite 'rising' lights. Thus, the discriminator fulfils the same function as the 'memory pointer' on a traditional barometer.

Pressure sensor

The pressure sensor (**Fig. 2**) is a Type HS20 from Bosch. It contains a wafer of piezo-electric material (see **Fig. 3**), which

has the property of generating a voltage across it when it is subjected to pressure. Voltage and pressure are in direct proportion, that is, the larger the pressure, the larger the voltage—see **Fig. 4**.

The sensor also contains a temperature-compensated measurement amplifier which ensures that temperature variations have virtually no effect on the measurement.

Circuit description

In the circuit of **Fig. 5**, IC₅ is the pressure sensor. To provide temperature compensation for the measurement amplifier, the 5 V supply to the sensor is regulated (IC₂).

The output of the sensor is fed to IC₁, which raises the signal to the required level. The offset of the op amp is compensated with P₁. The amplification, and thus the sensitivity of the circuit, is set with P₂. The output of the op amp is applied to both IC₃ and IC₄.

IC₃ is an LED driver that functions as a sort of digitized voltmeter whose display is formed by a row of ten LEDs. To ensure correct measurements, the IC has an internal voltage reference with which the input potential is compared. The same reference voltage is applied to IC₁ via R₂.

The operation of IC₃ is determined by resistors R₁₁–R₁₃ and preset P₃. These components fix the potential at which the LEDs for the lowest (D₁) and the highest (D₁₀) barometric pressure light.

Series resistors to limit the current through the LEDs are not required since the diodes are driven by a constant-current source.

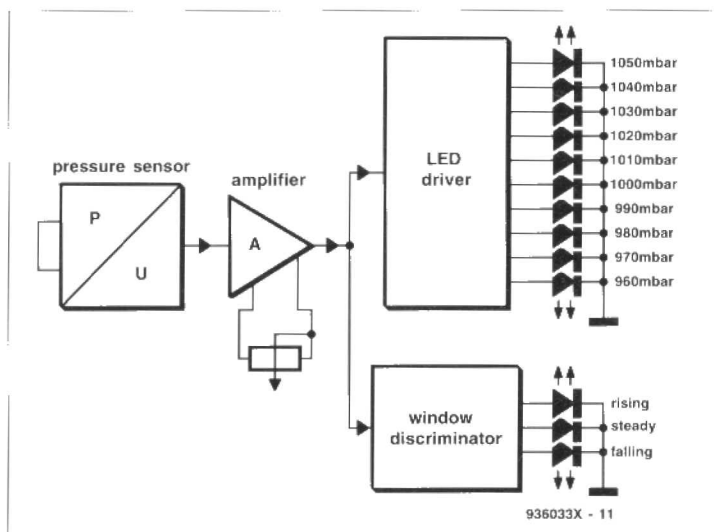


Fig. 1. Block diagram of the electronic barometer.

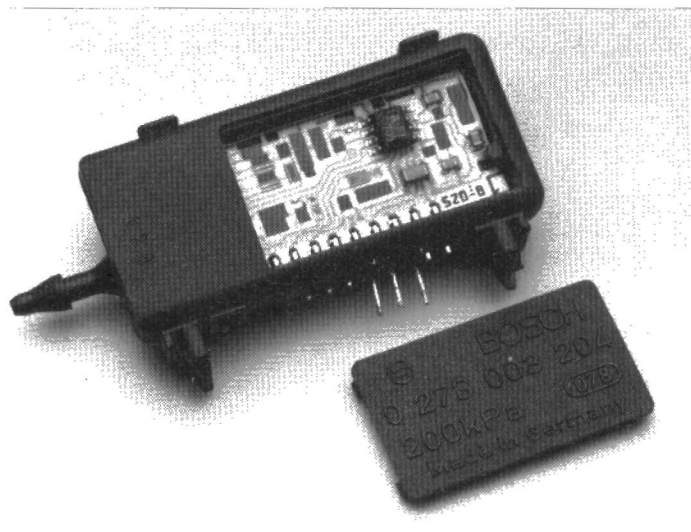


Fig. 2. The Type HS20 pressure sensor from Bosch.

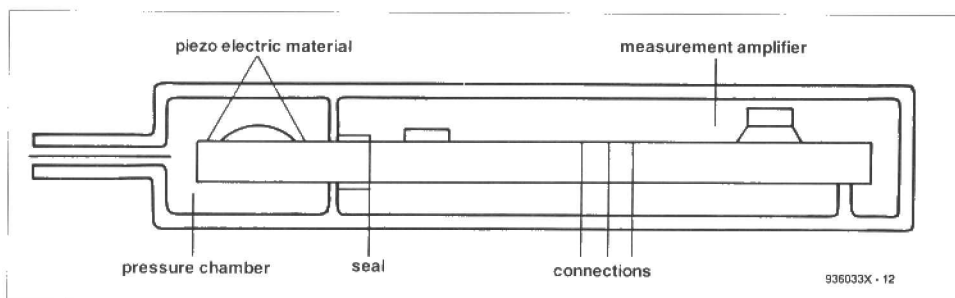


Fig. 3. Diagrammatic representation of the pressure sensor.

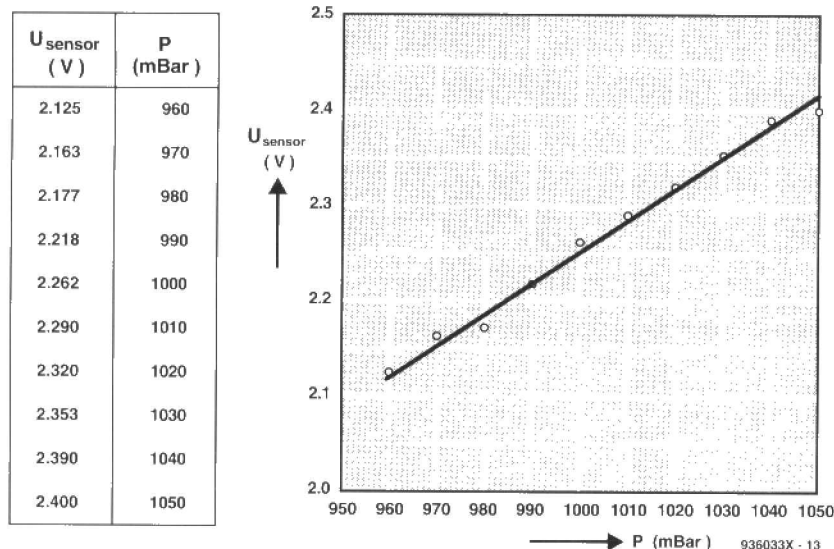


Fig. 4. Pressure vs voltage - data and characteristics - of the HS20.

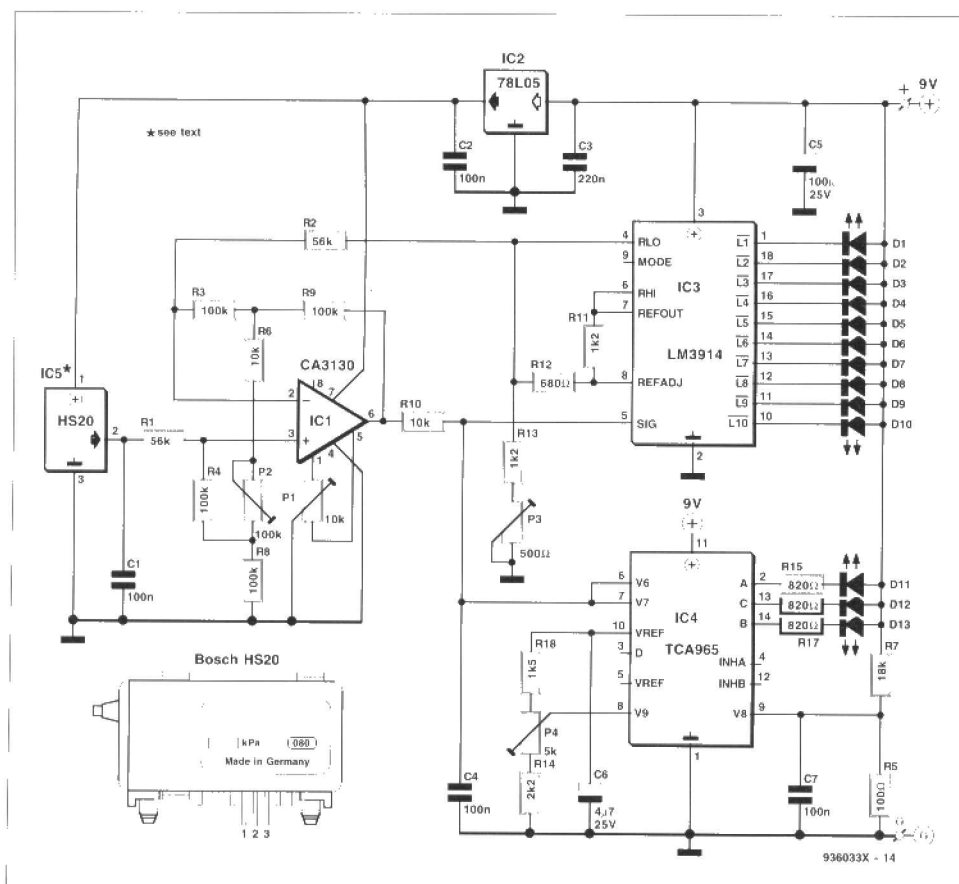


Fig. 5. Circuit diagram of the electronic barometer.

The circuit around IC₄ functions as the trend indicator. It shows the change in air pressure by means of D₁₁-D₁₃. The first indicates a rise and the last a fall in air pressure, while D₁₂ shows no change (steady). The centre of the 'window' is set with P₄ (adjusted until D₁₂ just lights).

Construction

The barometer is intended to be built on the printed-circuit board shown in Fig. 7. Start by enlarging the holes for adjusting presets P₁ and P₂ to 2-3 mm. These holes make it possible to calibrate the circuit from the front as well as from the back.

Place all ICs in suitable sockets, except IC₅, which should be soldered direct on to the board.

Make sure that electrolytic capacitors C₅ and C₆ are mounted correctly.

To ensure that all LEDs are at the same height, use a jig as shown in Fig. 6.

When the board has been completed (Fig. 8), mount it in a home-made perspex box: (perspex avoids having to drill holes for the LEDs).

Calibration

Connect a suitable voltage source (9 V battery or 9 V mains adaptor) to the barometer. Set P₂ to the centre of its travel and interconnect pins 2 and 3 of IC₁. Turn P₁ until the voltage at pin 6 of IC₁ is zero (or very nearly so). Remove the link between pins 2 and 3 of IC₁.

Use a traditional barometer and adjust P₃ so that the electronic barometer and the traditional one show the same air pressure.

Make a pressure chamber as shown in Fig. 10. This consists of a bowl in which both barometers fit. Cover the bowl airtight with a transparent lid (or heavy-duty clingfilm). Press lightly on the lid or clingfilm, which alters the air pressure inside the bowl. If the two barometers do not show the same pressure, open the lid and adjust P₂. If the reading of the electronic barometer

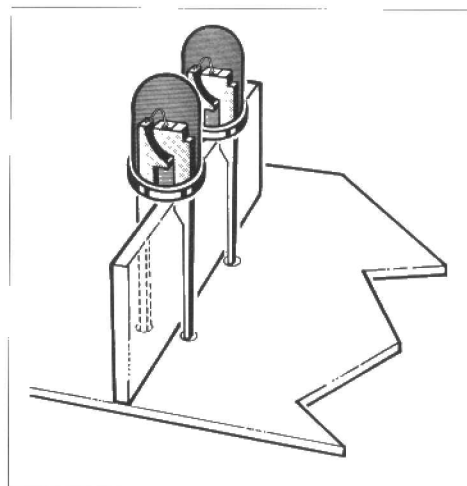


Fig. 6. Home-made jig to ensure that all LEDs are mounted at the same height.

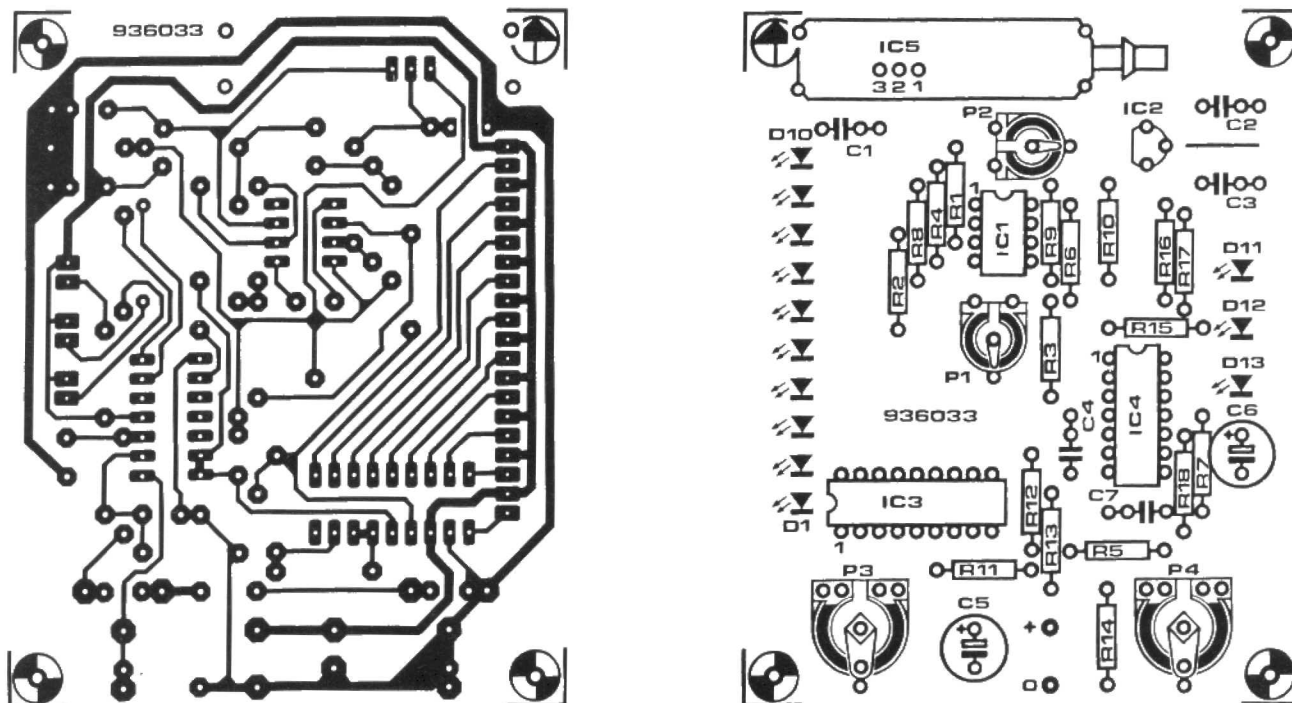


Fig. 7. Printed-circuit board for the electronic barometer.

changes when P_2 is adjusted, readjust P_3 until the two barometers show the same air pressure again. Close the lid and again check that the readings are the same when the lid is depressed slightly. Repeat this procedure as often as necessary to get equal readings.

Calibration may also be carried out with the data in Fig. 4. Remove the sensor from the board and apply a voltage shown near the top of the table in Fig. 4 to pin 3 of IC_1 and adjust P_2 and P_3 so that the LED associated with the chosen voltage level just lights. Repeat this procedure with all the voltage shown in the table in Fig. 4.

Finally, adjust P_4 until D_{12} just lights.

Parts list

Resistors:

$R_1, R_2 = 56 \text{ k}\Omega$

$R_3, R_4, R_8, R_9 = 100 \text{ k}\Omega$

$R_5 = 100 \Omega$

$R_6, R_{10} = 10 \text{ k}\Omega$

$R_7 = 18 \text{ k}\Omega$

$R_{11}, R_{13} = 1.2 \text{ k}\Omega$

$R_{12} = 680 \Omega$

$R_{14} = 2.2 \text{ k}\Omega$

$R_{15}, R_{16}, R_{17} = 820 \Omega$

$R_{18} = 1.5 \text{ k}\Omega$

$P_1 = 10 \text{ k}\Omega$ preset, horizontal

$P_2 = 100 \text{ k}\Omega$ preset, horizontal

$P_3 = 500 \Omega$ preset, horizontal

$P_4 = 5 \text{ k}\Omega$ prereset, horizontal

Capacitors:

$C_1, C_2, C_4, C_7 = 100 \text{ nF}$

$C_3 = 220 \text{ nF}$

$C_5 = 100 \mu\text{F}, 16 \text{ V}$

$C_6 = 4.7 \mu\text{F}, 16 \text{ V}$

Semiconductors:

D_1 – D_{10}, D_{13} = LED, 3 mm, red

D_{11} = LED, 3 mm, green

D_{12} = LED, 3 mm, yellow

Integrated circuits:

IC_1 = CA3130

IC_2 = 78L05

IC_3 = LM3914

IC_4 = TCA965

IC_5 = HS20 (Bosch)

Miscellaneous:

Spindles for P_3 and P_4

Enclosure (home made; perspex)

PCB Order no. 936033 - see p. 70

[936033]

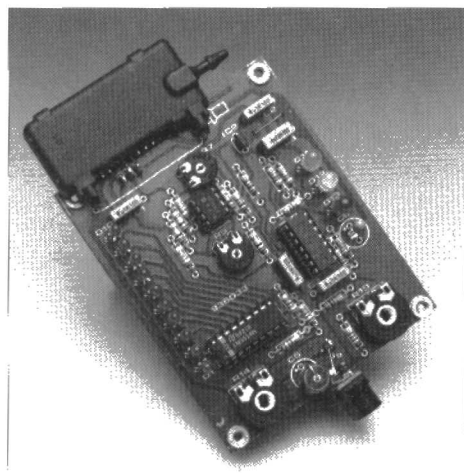


Fig. 8. Completed prototype.

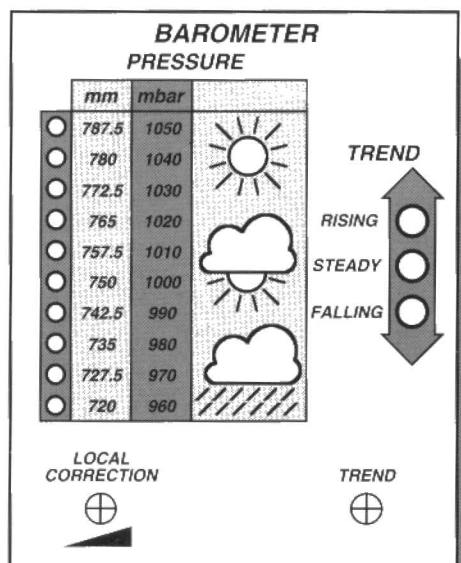


Fig. 9. Suggested front panel layout (scale 8:10).

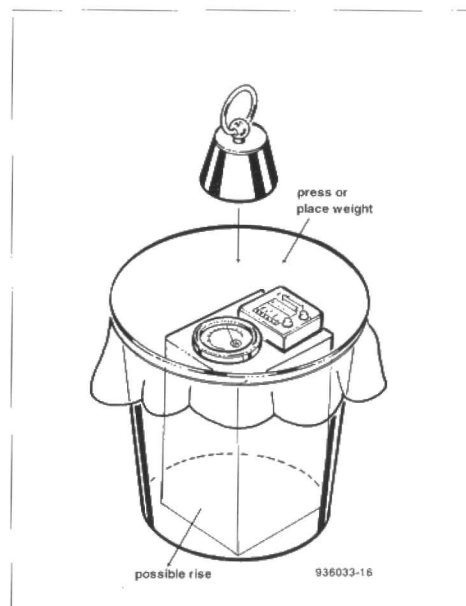


Fig. 10. Home-made pressure chamber for calibrating the barometer.

APPLICATION NOTE

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by *Elektor Electronics* or its consultants.

New amplifiers simplify wideband techniques

A Maxim Application

Limited performance in transconductance amplifiers has hampered their acceptance for years, with the exception of the few applications tailored to their capabilities. But two new products from Maxim promise to widen the scope of such amplifiers. The Maxim parts offer better specs for established circuits, and their unique architectures offer the prospect of entirely new applications.

MAX435/MAX436 amplifiers are open-loop devices that provide accurate gain without feedback. V_{OUT}/V_{IN} gain is the product of an internal current gain ($4 \pm 2.5\%$ in the MAX435; $8 \pm 2.5\%$ in the MAX436), and the ratio of an output impedance Z_L to the user-connected 'transconductance network' (Fig. 1). Z_L is a 2-terminal network connected across the amplifier's Z_+ and Z_- terminals. The MAX435 has differential outputs while the MAX436 has a single-ended output.

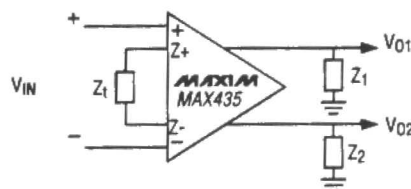
Because Z_L or Z_t (or both) can be frequency-shaping networks, the Z_L/Z_t ratio can implement some interesting transfer functions. A resistor ratio (times the internal current gain) simply sets a desired voltage gain. Replacing Z_L with a parallel-RC network produces a lowpass response, and replacing Z_t with a series-RC network produces a highpass response. Combining the parallel-RC Z_L and series-RC Z_t produces a bandpass filter. Or, by replacing Z_t with a crystal or series-LC network, you can create a high- Q tuned amplifier.

Each of these configurations is elevated to new levels of performance by the amplifiers' high speed: the MAX435 has a 275 MHz bandwidth with $800 \text{ V } \mu\text{s}^{-1}$ slew rate, and the MAX436 has a 200 MHz bandwidth with $850 \text{ V } \mu\text{s}^{-1}$ slew rate. Both offer 18 ns settling times ($\pm 1\%$) for 0.5 V step inputs, and both feature exceptional CMRRs of 53 dB at 10 MHz. Both have fully differential, symmetrical, high-impedance inputs. Input offset voltages (300 μV typical) are much lower than those of most high-speed op amps. The secret of high speed lies in the MAX435/MAX436 architecture. Con-

TWO EQUATIONS:

$$V_{O1} = K \cdot \left(\frac{Z_1}{Z_t} \right) V_{IN}$$

$$V_{O2} = -K \cdot \left(\frac{Z_2}{Z_t} \right) V_{IN}$$



* $K = \pm 2.5\%$ (MAX435), $8 \pm 2.5\%$ (MAX436)

GAIN IS SET BY A RATIO OF TWO IMPEDANCES AND AN INTERNAL CURRENT GAIN FACTOR (K).

950060-11

Fig. 1. Simple equations and freedom from instability ease the application of transconductance amplifiers.

sider the MAX435 (Fig. 2). With zero volts across V_{IN+} and V_{IN-} , the currents from I_1 and I_2 are mirrored and multiplied, producing 12 mA in Q_1 and Q_2 . These currents each match 12 mA from a current source in the output stage, producing a zero differential output at I_{OUT+} and I_{OUT-} .

Connecting a positive differential voltage across V_{IN+} and V_{IN-} diverts some of the I_1/I_2 current through Z_t

(connected between Z_+ and Z_-), causing an imbalance in the Q_1/Q_2 currents. The result is a net differential output current at I_{OUT+} and I_{OUT-} . Time delays are very short, because the signals propagate as steered currents (rather than voltages), and because all stages in the signal path receive substantial bias currents. The following applications are made possible by these and other special capabilities

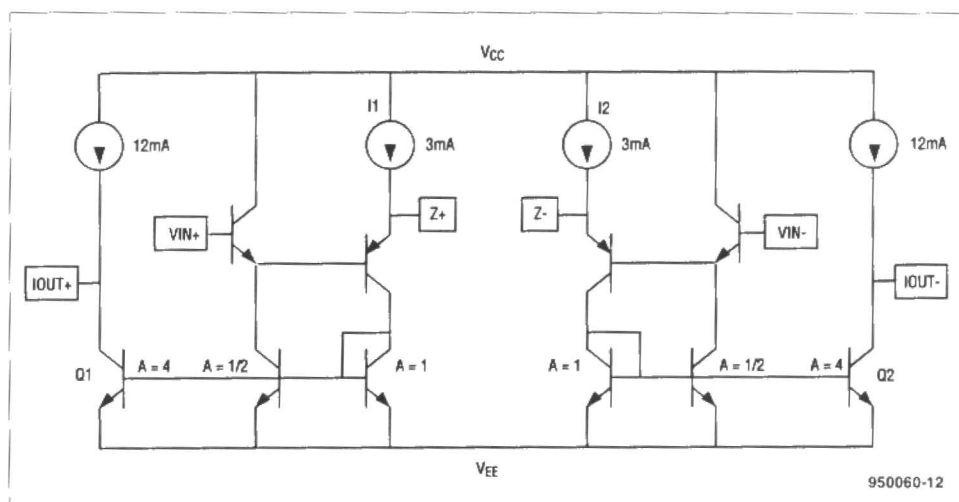


Fig. 2. This simplified diagram shows basic circuitry in the MAX435 differential-output transconductance amplifier. An external resistor, R_{SET} , controls the four current sources, and its nominal value of 5.9 k Ω produces the current levels shown.

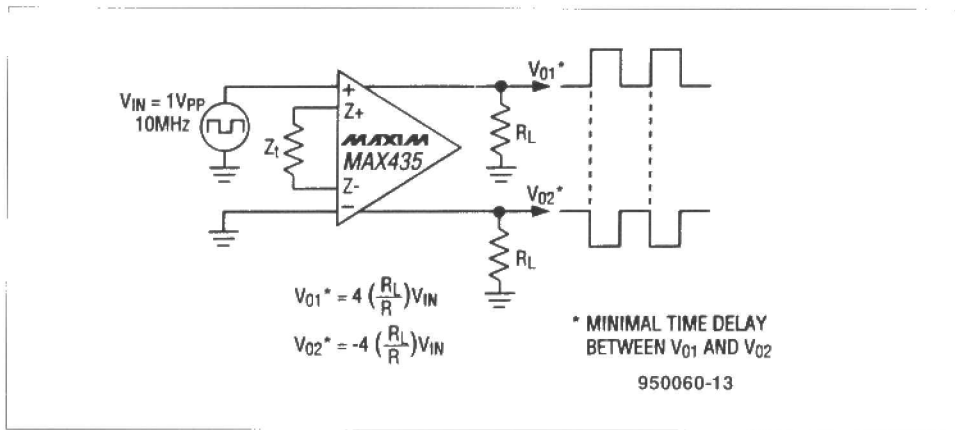


Fig. 3. Differential outputs make the MAX435 a convenient single-package phase splitter.

in the MAX435/MAX436 amplifiers.

Because MAX435 and MAX436 outputs are high-impedance current sources, you can create a summing amplifier simply by tying two or more outputs together. No additional components are required, except a load resistor, to develop the output voltage. Another intrinsic function is that of phase splitter—the MAX435 differential outputs provide inverted and non-inverted (0° and 180°) versions of the input signal.

As phase splitter, the MAX435 offers a convenient, single-IC differential drive for balanced transmission lines (Fig. 3). The IC's excellent common-

mode rejection (90 dB at d.c.; -53 dB at 10 MHz) assures reliable transmissions.

The amplifiers' high-impedance inputs and outputs allow them to operate as monolithic impedance transformers (Fig. 4). The high-impedance, true-differential inputs (800 k Ω typical) let you connect any reasonable value of input termination resistance. Similarly, the current-source outputs have a relatively high source resistance (3.2 k Ω typical) that lets you connect any reasonable value of load resistance.

The main advantage of these circuits over magnetic transformers is in their low-end frequency response, which ex-

tends to d.c. Baseband video, for example, has frequency components ranging from 4.5 MHz to below 60 Hz. A line transformer with flat frequency response over that range would be very bulky and expensive. Flexibility is another advantage for the IC approach: by changing one or two resistors you can match the transmitter and receiver to a variety of cables in the same system.

As another illustration of the need for impedance matching, coaxial cables for high-speed signals must be carefully terminated in their characteristic impedance to ensure maximum power transfer and minimum distortion. To obtain optimum performance from 50 Ω cable, therefore, you must terminate each end of the cable with 50 Ω .

Further description

Voltage-mode amplifiers have low output impedance, so they require a series-resistor interface to coaxial cable. But MAX435/MAX436 amplifiers have high-resistance current-source outputs that require a parallel connection of the termination resistor (i.e., in shunt with the cable). Note that back-terminating the cable this way reduces the circuit voltage gain by half (Fig. 5).

MAX435/MAX436 amplifiers offer the user several 'control handles'. For top performance in this application and others, you should be aware of the

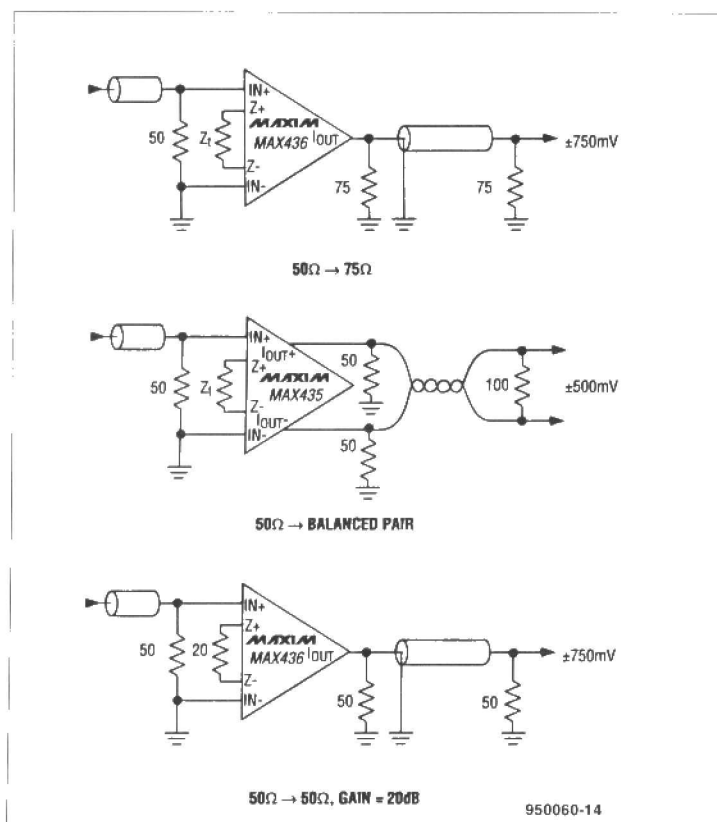


Fig. 4. Independent settings for output current and load resistance enable MAX435/MAX436 amplifiers to act as impedance transformers. Supply voltages are ± 5 V, and the R_{SET} resistors (between the amplifiers' I_{SET} terminals and ground) are 5.9 k Ω .

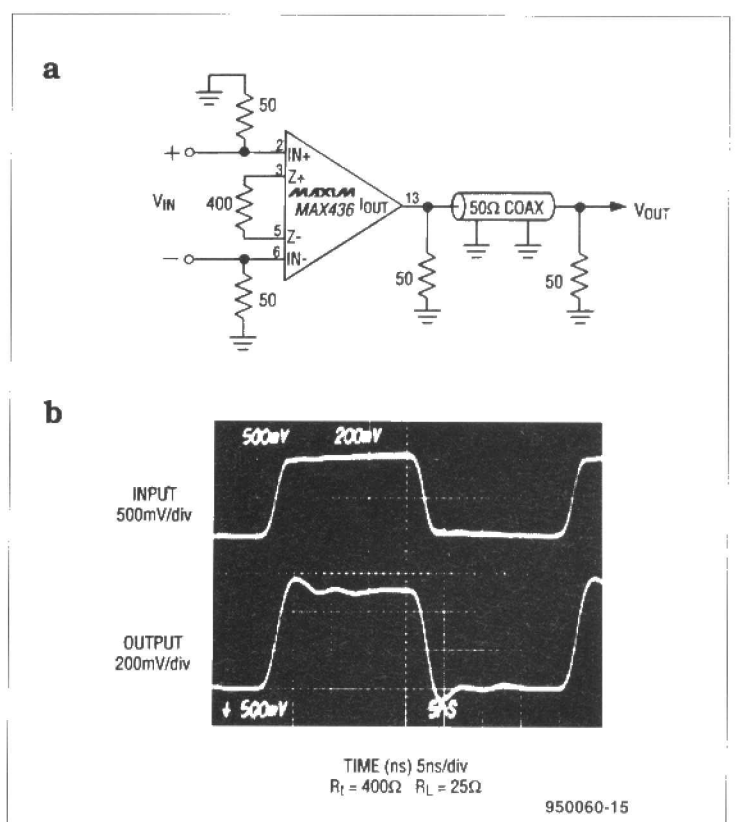


Fig. 5. As a coaxial driver (a), the MAX436 transconductance amplifier handles fast pulses with minimal overshoot and ringing (b).

amplifiers' shutdown capability, their adjustable load-current limits, and the factors that affect their accuracy.

First, the internal current sources are controlled by an external resistor, R_{SET} , connected between the I_{SET} terminal and the V_- supply voltage (Fig. 2). Both amplifiers operate on ± 5 V. The standard R_{SET} value for which all specifications are guaranteed is 5.9 k Ω , and this value sets the limit for maximum I_{OUT} : ± 20 mA for the MAX436, and ± 10 mA per output for the MAX435. By connecting a larger-valued R_{SET} , you can reduce the amplifiers' supply current and power dissipation (along with the maximum I_{OUT}).

You can also increase the output current by decreasing R_{SET} , but be careful to ensure that the higher current does not combine with a particular operating condition to exceed the package power-dissipation rating. Removing R_{SET} altogether provides a partial shutdown of the amplifier. Without R_{SET} , the room-temperature supply currents (normally 35 mA) drop to 450 μ A $\pm 25\%$ for the MAX435 and 850 μ A $\pm 25\%$ for the MAX436.

DC accuracy in the MAX435 and MAX436 is affected by the input offset voltage, V_{OS} , the output offset current, I_{OS} , and tolerance on the internal current gain, K , as well as tolerance on the external impedances Z_i and Z_L . V_{OS} is caused by a V_{BE} mismatch at the input stage (like the V_{OS} in bipolar voltage amplifiers), and is measured between the Z_+ and Z_- terminals—with Z_i removed and the inputs, IN_+ and IN_- , grounded. V_{OS} produces a small error current in Z_i during normal operation. Multiplied by K , it produces an output

error current, even with no differential input voltage applied.

I_{OS} is a separate and independent output error that is caused by imperfectly matched devices in the output-current mirrors. Though measured under the same conditions as the V_{OS} measurement, I_{OS} does not vary with input voltage. Combining the I_{OSD} and V_{OS} effects yields a net error in output voltage. The MAX435's differential output error, $V_{ERR}(DIFF)$, for instance, is:

$$V_{ERR}(DIFF) = (V_{ERR+}) - (V_{ERR-}),$$

where

$$V_{ERR+} = (R_L+)[(I_{OS+}) + K(V_{OS}/R_L)]$$

and

$$V_{ERR-} = (R_L-)[(I_{OS-}) - K(V_{OS}/R_L)].$$

I_{OS} is -20 μ A typical (± 100 μ A max), and V_{OS} is 0.3 mV typical (3.0 mV max).

Similarly for the MAX436,

$$V_{ERR} = (R_L)[I_{OS} + K(V_{OS}/R_L)],$$

where I_{OS} is 6 μ A typical (± 100 μ A max), and V_{OS} is 0.3 mV typical (3 mV max).

Twisted-pair video

The MAX435 and MAX436 amplifiers provide a differential-out/differential-in combination that is well suited for one-way transmission of video signals over a twisted-pair cable (Fig. 6). As a bonus, the MAX436 Z_i network provides a means for line equalization and

gain adjustment.

Replacing coaxial cable with twisted-pair cable saves cost in many applications that do not require the higher bandwidth of coax. These applications have initially included LANs (local area networks) and LONs (local operational networks). But twisted-pair cable is more compact than coaxial cable, and the miles of unused twisted-pair cabling that already reside in the phone system of existing buildings may inspire additional applications. Baseband (composite) video can be transmitted over these cables as far as 5000 ft (1500 m) with surprising quality.

Twisted-pair video transmission works best with a single channel of baseband video. Many applications require such transmissions within a building; an obvious example is the separate video channels routed from individual surveillance cameras to a security office. Other closed-circuit TV (CCTV) systems are found in retail stores, supermarkets, airports, and schools.

Twisted pairs resist differential noise pickup: because a pair is twisted, any differential current induced by an interfering EM field in one loop gets cancelled in the following loop. Common-mode noise, on the other hand, must be rejected by a balanced (differential) circuit at the receiver. Twisted-pair cables must also be terminated in their characteristic impedance to minimize the reflections caused by line discontinuities.

For twisted pairs exceeding about 200 ft (65 m), bandwidth falls short of the typical baseband-video bandwidths (4–5 MHz). But these cables are satis-

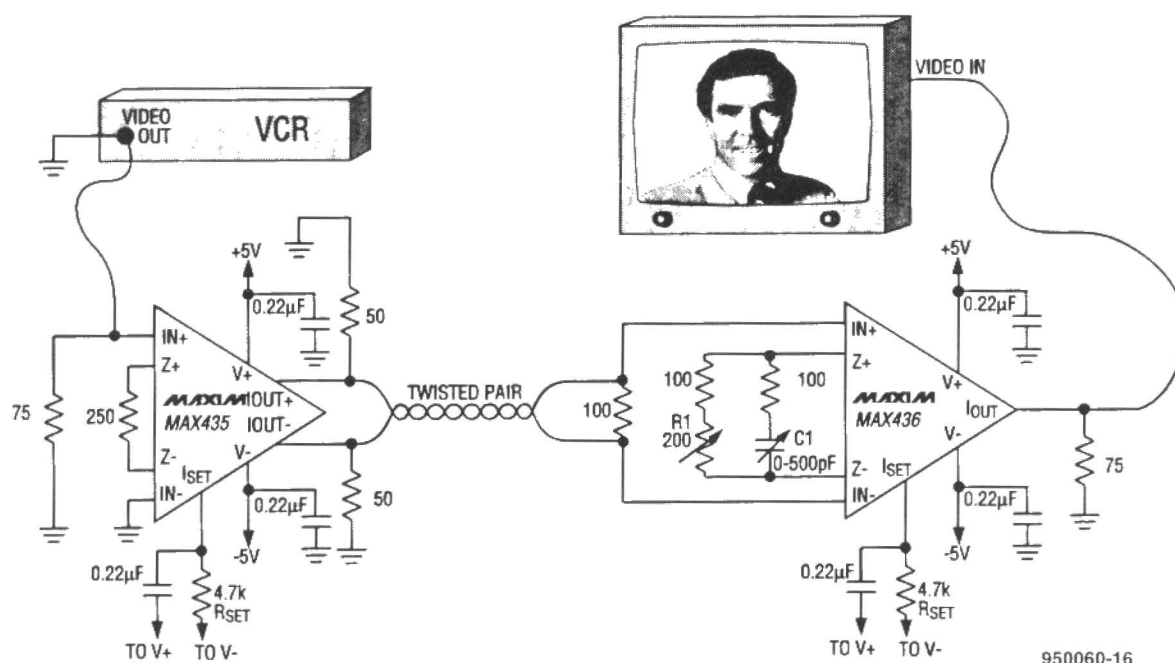


Fig. 6. Two transconductance amplifiers and a twisted-pair cable transmit baseband video for 5000 ft (1500 m) or more.

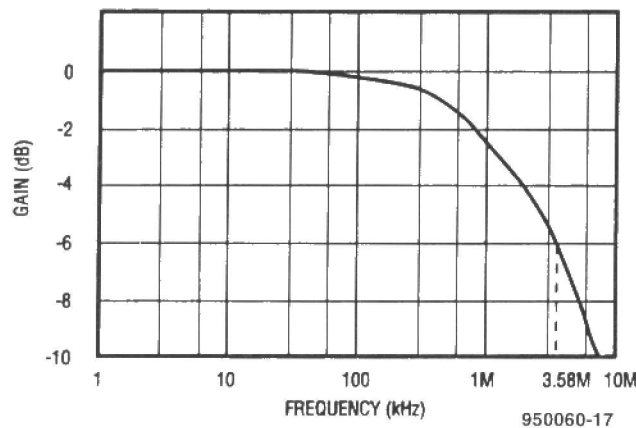


Fig. 7. Inexpensive burglar-alarm cable [twisted pair, 500 ft (165 m), 22 gauge] attenuates the 3.58 MHz colourburst frequency of baseband video by 6 dB.

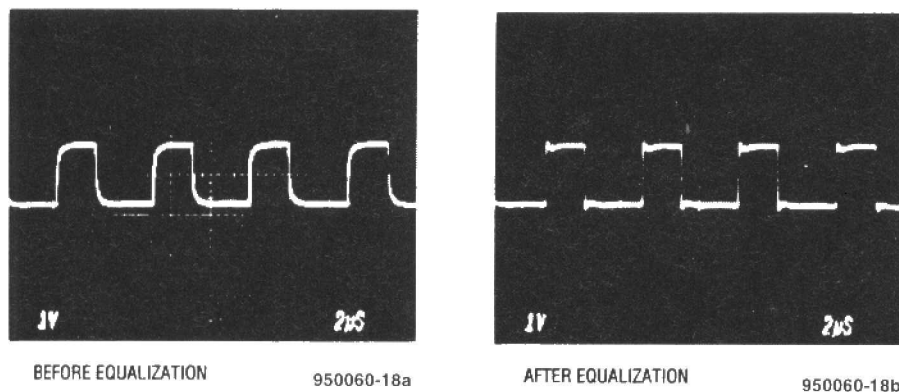


Fig. 8. These before-and-after waveforms show the effect of adjusting for optimum brightness and colour via R_1 and C_1 (Fig. 6), while observing the monitor display.

factory for baseband video if you equalize your receiver, provide an NTSC monitor with automatic gain compensation, and choose quality (wideband) cable.

Stranded and unstranded wires exhibit similar bandwidths, but the highest-bandwidth cables are unshielded, and have insulation of low dielectric constant between the conductors. Polyethylene or polypropylene insulation is recommended for new installations. For twisted-pair video transmissions under 1000 ft (330 m), use common 24 AWG (25 SWG) telephone wire. For longer distances, you can improve the video fidelity by using larger wire.

The differential-output MAX435 of Fig. 6 eliminates the need for a balun (balanced-to-unbalanced) transformer or the two-driver alternative—one single-ended inverting driver and one single-ended non-inverting driver. The MAX435 drives the balanced twisted-pair cable from a ground-referred input signal (in this case, from a VCR's VIDEO OUT baseband signal).

At the driver end of the cable, each conductor is terminated with a 50 Ω resistor to ground. The resulting 100 Ω

between conductors is an appropriate match for the cable's characteristic impedance. A mismatch can degrade the video, but it can not affect amplifier stability because the MAX435 has no feedback. Output amplifiers are ± 0.5 V.

At the receiver end, a MAX436 amplifier converts the balanced input channel to a single-ended output. Again, the proper line termination is

100 Ω between cable conductors at the IN+ and IN- inputs. The Z_1 impedance network across Z_+ and Z_- adds adjustable gain (about 6 dB) to compensate for a 6 dB loss introduced by the termination resistors. The network's adjustable capacitor also provides line equalization (frequency compensation) if required. Load resistance is 50 Ω , consisting of the 75 Ω resistor in parallel with 150 Ω at the monitor's input port.

Test results

Operating with 500 ft (165 m) of inexpensive, 22-gauge, twisted-pair burglar-alarm cable, the circuit in Fig. 6 attenuates the baseband video's 3.58 MHz colourburst frequency about 6 dB (Fig. 7). Despite the distortion, no degradation of colour saturation was observed at the NTSC monitor used in this test. No degradation was expected, however: this monitor compensates for signal attenuation by calibrating automatically against test patterns in the vertical interval test signal (VITS).

The monitor's automatic loss equalization is robust; it compensates for colourburst attenuation as high as 10 dB, displaying an excellent picture with no noticeable colour fading or loss of horizontal resolution. Further attenuation, however, produces poor chroma and a horizontal fuzziness that makes it difficult to read displayed text.

Under that condition, you can still achieve compensation via adjustments at the MAX436 Z_1 network: R_1 adjusts brightness by boosting the overall gain to compensate for ohmic losses, and C_1 introduces a pole/zero pair in the receiver circuit, which adjusts for colour by extending the channel bandwidth. Because compensation is introduced at the receiver, you can simply view the display and adjust for the best picture. Before-and-after waveforms show the result of this equalization (Fig. 8).

Next, consider the Fig. 6 circuit op-

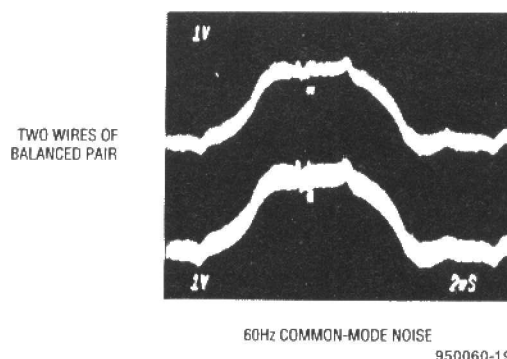
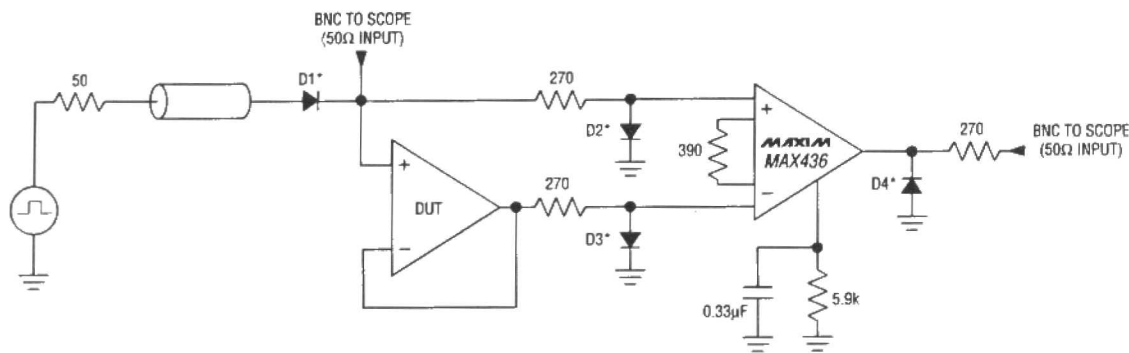


Fig. 9. Thanks to 60 dB CMRR in the MAX436, the display in Fig. 6 is unaffected when these 60 Hz common-mode signals are deliberately added to each wire of the balanced cable.



* D1, D2, D3, D4, ARE 1N5711's FROM HEWLETT PACKARD, SELECTED FOR FAST TURN-ON TIME.

950060-20

Fig. 10. Wideband differential inputs and an absence of output saturation suit the MAX436 for use in settling-time fixtures.

erating with 1000 ft (330 m) of twisted-pair telephone cable. The test setup included a length of unused twisted pair in a trunk cable between two Maxim buildings, two jumper connections in the phone-patch room, and additional twisted-pair cable that was routed through hallways to complete the transmission path.

This system easily transmitted baseband video from a VCR, producing an excellent picture with R_1 and C_1 at their nominal settings (no equalization required). High noise immunity was illustrated by coupling 60 Hz common-mode noise to the line (Fig. 9). The MAX436 CMRR (60 dB at 60 Hz) removed this noise with no evidence of beating in the display. On the other hand, driving the cable in an unbalanced mode produced poor results as expected.

Although tests on the Fig. 6 circuit involved only NTSC video signals, the circuit should provide comparable performance for PAL signals, which have a chroma carrier of 4.43 MHz.

Settling time measurements

Quick response and avoidable output saturation favour the MAX436 for use in measuring the settling time of slower amplifiers (Fig. 10). In the test circuit, you configure the device on test (DUT) as a voltage follower and drive its inputs with a square wave. The MAX436 observes DUT settling time by comparing its input and output signals.

The applied square wave appears quickly at the MAX436's non-inverting input, but is delayed by propagation time through the DUT before reaching the inverting input. The result is a brief but high-amplitude signal (clamped by D_2 and D_3) that appears between the MAX436's in-

puts before the DUT can settle. If the MAX436 were a voltage-mode amplifier, this large differential input would cause the output transistors to saturate, thereby corrupting the settling-time measurement with overload-recovery time.

With properly chosen gain elements, however, the MAX436 can accommodate input signals that span its entire input common-mode range without saturation in the output stage. This characteristic suits the amplifier for settling-time measurements of digital-to-analogue (D-A) converters as well as high-speed op amps. (Following a 0.5 V common-mode step, the MAX436 itself settles to $\pm 0.1\%$ in about 17 ns). Note that this common-mode response is faster than the response to a differential signal, in which the output response time is limited by the slow rate.

Figure 11 illustrates the response of a MAX442 (2-channel, 140 MHz video multiplexer and amplifier) operating as a DUT in the circuit of Fig. 6. The input step is 2 V in this case. Note that the initial output level (40 mV) should ideally be zero. It represents the differ-

ence in forward voltages for the Schottky clamp diodes, D_2 and D_3 , multiplied by voltage gain from the MAX436 to the scope (which is near unity). This initial voltage has no effect on the settling measurement.

You can define settling time either from the beginning of the input's downward transition (which includes the DUT's propagation delay), or from the first output transition (a useful parameter in video applications). Because the MAX442's propagation delay is small, its $\pm 0.1\%$ settling time measures about 42 ns either way. The mid-screen graticule line is 0 V, the first cursor line is the final-settling level, and the next cursor line marks the boundary for $\pm 0.1\%$ settling.

References

- MAX435/MAX436 Data Sheet; Maxim Integrated Products, 1992.
- Carol Cable Catalog; Carol Cable Company, Inc., Highland Heights, KY (USA), 1989
- Reference Data for Radio Engineers, 4th edition; International Telephone and Telegraph Corporation, Sept. 1989.
- Transmission Systems for Communications, revised 4th edition; Members of the Technical Staff, Bell Telephone Laboratories, Dec. 1971.
- Vargha, Douglas, conversations at Maxim Integrated Products, Feb. 1993

[950060]

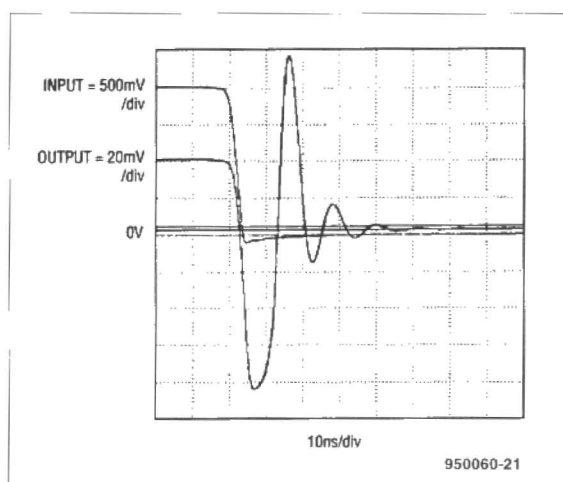
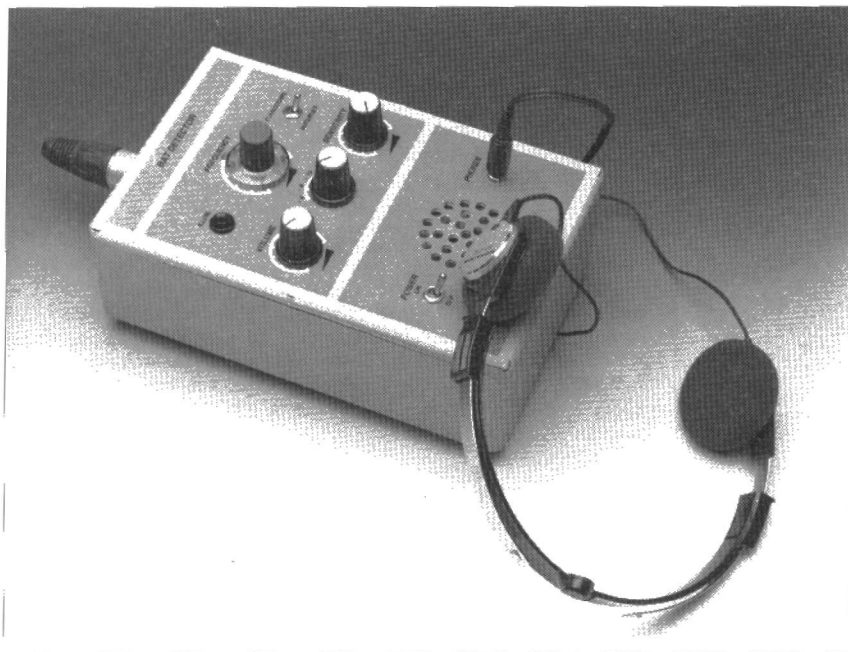


Fig. 11. Settling time for a MAX442 video amplifier in the Fig. 10 circuit is 42 ns.

Maxim Integrated Products
21C Horseshoe Park
Pangbourne
Reading RG8 7JW
England
Telephone (01734) 845 255

BAT DETECTOR

Design by L. Lemmens



The detector makes sounds at frequencies of 10–300 kHz audible to human beings. The conversion is carried out either by a superheterodyne circuit or a frequency divider. Although it enables listening to bats, and a number of other mammals, as well as insects, the detector is particularly useful for testing ultrasonic alarm equipment.

Human beings can only hear sounds in the frequency range of 20 Hz to 20 kHz and even that depends on age. There are many animals that have a much wider range of hearing: bats, dolphins and whales, for instance, can hear sounds at frequencies up to 200 kHz. The hearing range of man, some mammals and a few insects is given in **Fig. 1**. The vocal range is normally rather narrower: 70–80% of the hearing range.

The ultrasonic sounds made by bats and dolphins are not so much used to communicate (at least not as far as scientists are aware of), but rather as a means of navigation similar to man's radar and sonar systems.

Bats emit short bursts of ultrasonic tones to orient themselves and to locate food in the form of insects. These tones may be of constant frequency (CF) or they may vary in frequency, that is, be frequency modulated (FM). Some species of bat emit an 83 kHz burst of CF tones that are frequency modulated when they die out. Each tone lasts 30–40 ms. Another species emits frequency-modulated pulses that fall in frequency from 60 kHz to 30 kHz in 10 ms. The FM tones are used by all species to determine the distance to

the insect, while the CF tones serve to determine the relative speed with respect to the insect. The echoes returned by the insect also contain information about the speed at which the insect moves its wings: from this, the bat can determine the type and size of insect. The measurements made by the bat depend on two well-known physical phenomena: the Doppler effect and interference.

The Doppler effect is the apparent change of frequency caused by the relative motion of the source of radiation

and the observer. An example is the change in frequency of the sound heard when a train or aircraft is moving towards or away from an observer.

Interference is the interaction between two or more waves of the same frequency emitted by a coherent source. The wavefronts are combined according to the principle of superposition. In the case of the bat, the two waves are the emitted sound and that of the echo, which are combined in the ear of the bat.

Bats are very useful animals that cause no damage, harm no one, and are protected by law. They, and a number of birds, keep the insect population under control. For instance, a single bat consumes no fewer than 60 000 mosquitos during the summer. A bat has to eat a lot during the warmer season, because it loses about 25% of its body weight during hibernation. We should leave these interesting little animals in peace and quiet during their hibernation and also in spring when they are busily feeding and looking after their young family.

Nevertheless, the present detector can be used to study them during spring and summer: most bats can be heard at distances of 20–30 m (65–90 ft). This is not surprising when it is realized that some species emit ultrasonic sounds at a level of 100 dB (which is equivalent to that of a pneumatic hammer).

The divider in the detector enables the entire range of 10–300 kHz to be monitored, but it has the disadvantage of 'losing' the original waveform; only the frequency information is retained. However, the superheterodyne section of the detector leaves the original waveform intact, but can scan the frequency range only in segments 15 kHz wide. Also, the superheterodyne section is more sensitive than the divider.

Circuit description

The electret microphone in the circuit of **Fig. 2** picks up the ultrasonic sounds. It has an integral amplifier, which obtains its power supply via R_1

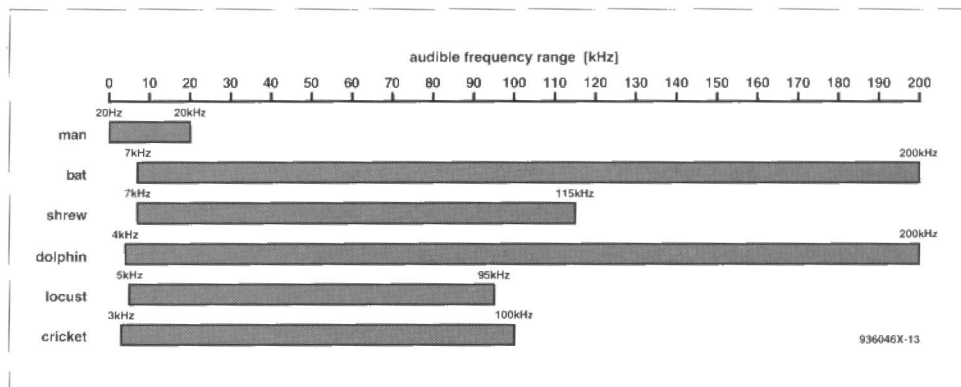


Fig. 1. Hearing range of man, some mammals and a few insects.

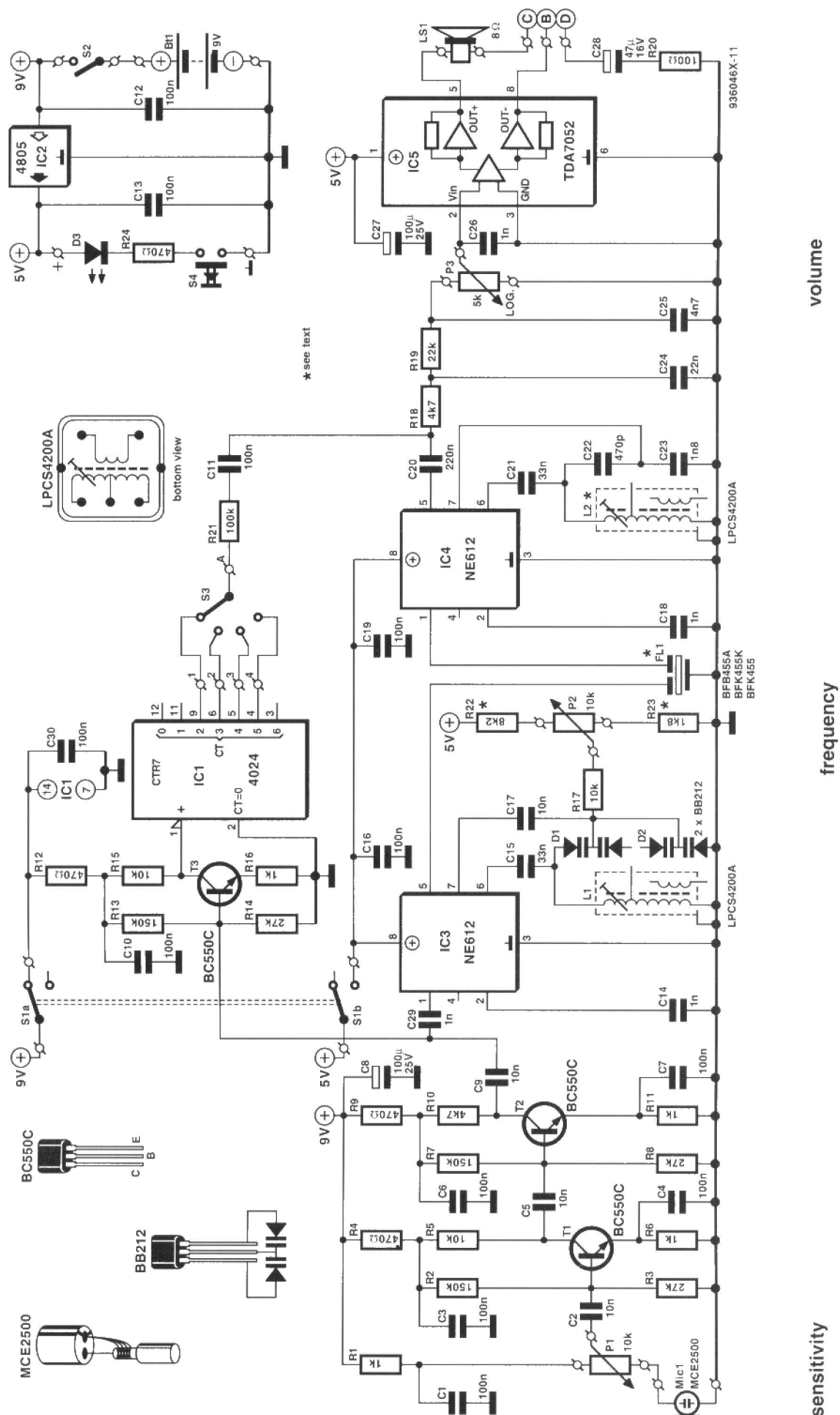


Fig. 2. Circuit diagram of the bat detector.

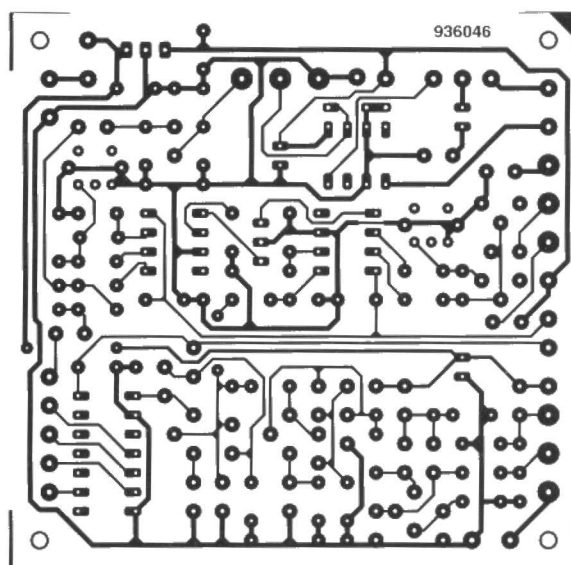
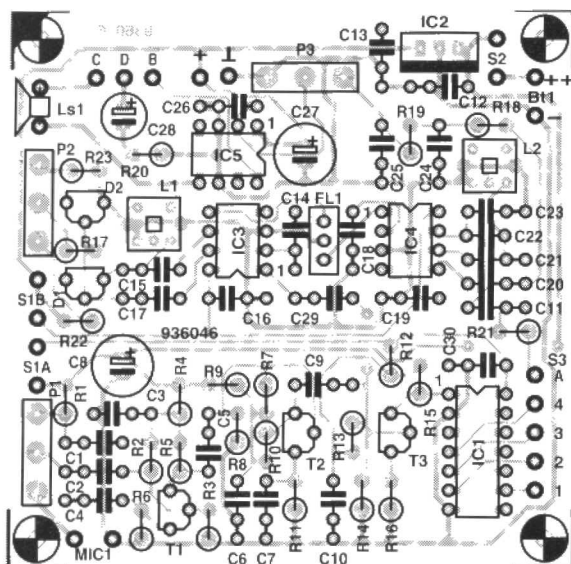


Fig. 3. Printed-circuit board for the bat detector.

and P_1 . The output of the microphone is applied to a two-stage preamplifier, T_1 and T_2 , via sensitivity control P_1 . The values of C_1 – C_7 and C_9 are small to ensure that frequencies below about 10 kHz (which are of no interest in the present application) are not magnified by the preamplifier. In other words, the preamplifier functions as an active high-pass filter, so that all frequencies in the wanted range are of about the same level.

As stated earlier, the detector provides two different means of converting ultrasonic sounds into audible ones: division and superheterodyning. Each has its own circuitry and the output of the preamplifier is, therefore, applied to two different sections in Fig. 2.

The section around T_3 and IC_1 is a frequency divider. The gain of T_3 (20 dB), determined by the ratio $R_{15}:R_{16}$, ensures that even with weak

inputs the signal at pin 1 of IC_1 is sufficient for the proper operation of the divider. At the same time, the gain is not so high that the circuit reacts to the ever-present ambient noise.

The frequencies of the signal applied to IC_1 are divided by a number of cascaded binary scalars. Although IC_1 has seven outputs, only those that give a scaling factor of 4, 8, 16 or 32 are used and selected with S_3 . For instance, with S_3 in position 4, an ultrasonic input of 32 kHz is divided by 32 and thus converted to a 1 kHz tone.

The output of IC_1 is applied to a.f. amplifier IC_5 via attenuator R_{21} .

The superheterodyne section is

based on IC_3 and IC_4 . In IC_3 , the output of T_2 is converted to a fixed intermediate frequency, i.e., of 455 kHz. This, in conjunction with bandpass filter FL_1 , makes it simple to extract the wanted signal from the spurious ones and noise.

To obtain a difference frequency of 455 kHz, the 10–300 kHz input signals are mixed with the output of a Colpitts oscillator that covers the frequency range of 465–755 kHz. Associated with the oscillator are inductor L_1 and varactors D_1 and D_2 . If, for instance, the incoming signal is 100 kHz, the oscillator in IC_3 must be tuned to 555 kHz to obtain a difference frequency of

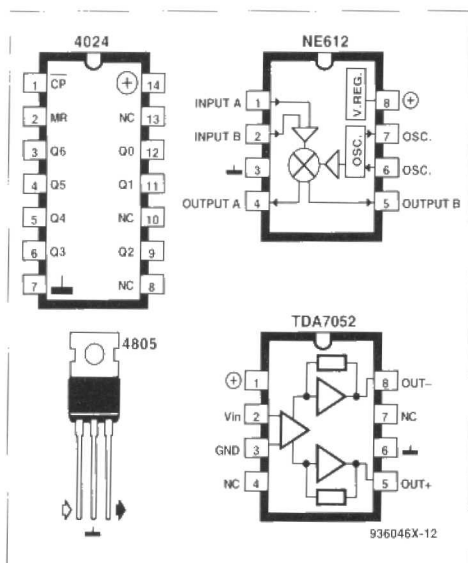


Fig. 4. Pinouts of the integrated circuits.

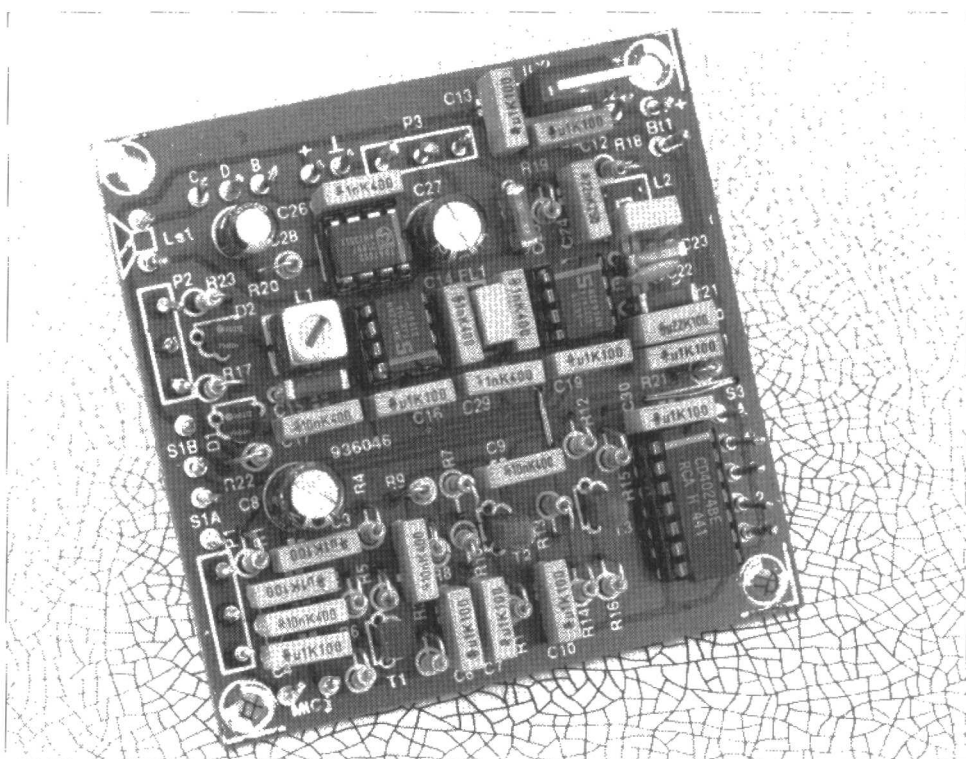


Fig. 5. Completed prototype printed-circuit board.

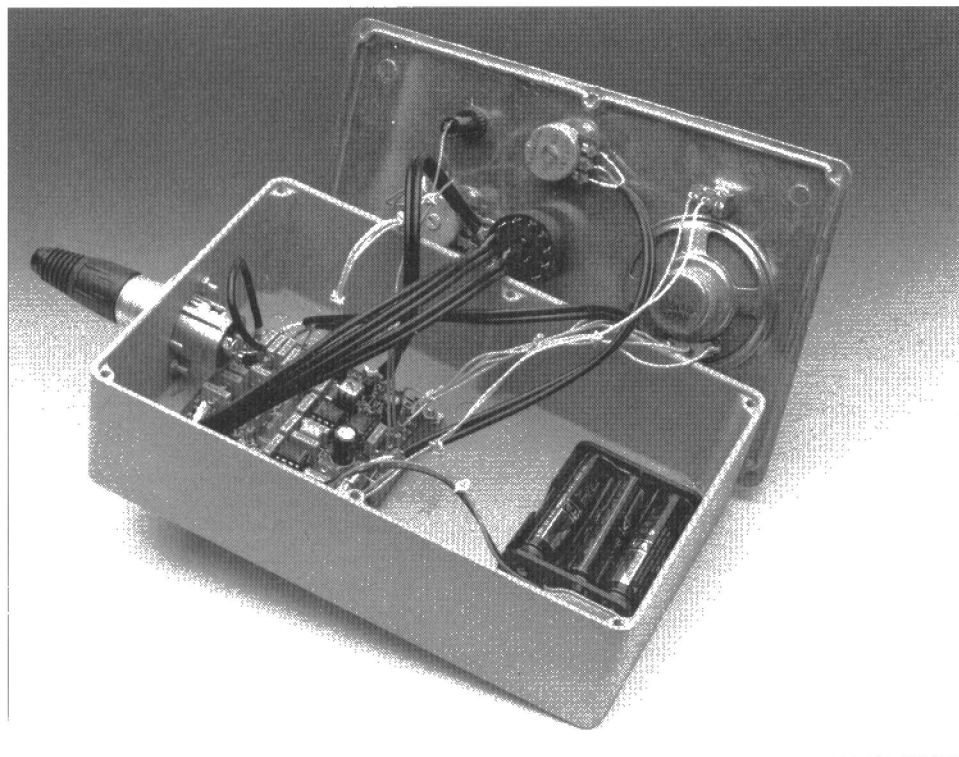


Fig. 6. completed prototype with top cover removed.

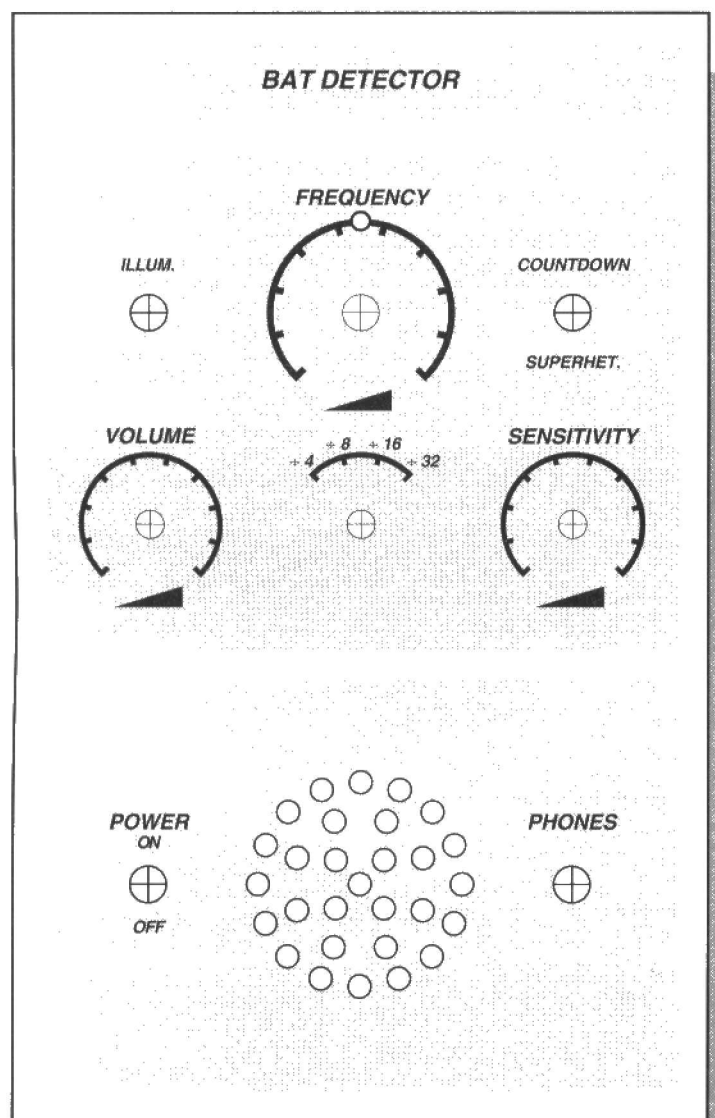


Fig. 7. Suggested front panel layout (scale 8:10).

455 kHz. The reason that of each of the two dual varactors only one half is used is that it enables constructors to use a lower inductance for L_1 . In that case, the oscillator frequency range lies somewhat higher; the second half of D_2 should then be connected in parallel with the other half to pull the range down again.

When the voltage across the varactors is a minimum, the capacitance is a maximum and the oscillator generates its lowest frequency (465 kHz). Turning P_2 to the position where the resistance between the wiper and junction R_{22} - P_2 is minimum, the oscillator generates its highest frequency (755 kHz).

Inductors L_1 and L_2 are 455 kHz i.f. transformers of which only the two outer windings are used. The integral parallel capacitor in both should be disabled by gently pushing a small screwdriver through its centre.

The 455 kHz signal is, of course, still not audible and it is, therefore, applied to a second mixer, IC_4 . The frequency of the oscillator in this stage is determined by L_2 - C_{22} - C_{23} . This is tuned to 452 kHz or 458 kHz in order to produce a 3 kHz tone (normal human hearing is at its most sensitive at this frequency). In the prototype, a frequency of 452 kHz was preferred since this ensures that when the input frequency rises, the audio output also rises.

The 3 kHz signal at the output of IC_4 (pin 5) is applied to a.f. amplifier IC_5 via double low-pass filter R_{18} - C_{24} and R_{19} - C_{25} . This filter also removes the higher harmonics from the rectangular output of the divider. Potentiometer P_3 is the volume control. The amplifier chip contains a driver stage and an output stage, which can drive a small loudspeaker or headphones.

Power for the detector is obtained from a 9 V (PP3 = 6F22) battery. The 5 V line is derived from this battery by regulator IC_2 . Although low-drop Type 4805 is preferred, a standard Type 7805 can be used, but the battery voltage should then not be allowed to drop below 8 V.

Switch S_1 serves to select 'division' or 'superheterodyne' operation.

Push-button switch S_4 serves to switch on D_3 which functions as pointer and illumination for the frequency scale around P_2 . The LED in the D_3 position (and its series resistor) may be replaced by a small bulb from an alarm clock.

Construction

The detector is preferably built on the printed-circuit board shown in **Fig. 3**. As usual, first mount the passive components, then the inductors and lastly the semiconductors and integrated circuits. It may be necessary when alter-

native types of inductor are used to drill out some of the relevant holes in the board. A photograph of the completed board is shown in **Fig. 5**.

The prototype detector is housed in a $188 \times 120 \times 57$ mm ($7\frac{3}{8} \times 4\frac{3}{4} \times 2\frac{1}{4}$ in) metal enclosure—see **Fig. 6**. As is seen, a somewhat smaller enclosure may do just as well.

The frequency scale in **Fig. 8** is intended to be glued around the hole for the frequency control. Note that this is just an example, since tolerances of the oscillator in IC₃ may make the positions slightly different. A calibrated scale is readily made with the aid of a frequency meter and/or signal generator.

The microphone may be mounted in a side of the enclosure or used as a separate entity connected to the detector by a length of screened audio cable.

Note that the jack socket for the headphones must be insulated from the enclosure by nylon washers and a nylon bush to prevent pins 5 and 8 of IC₅ being shorted to chassis.

Calibration

Connect the 9 V battery to the detector and switch on the supply with S₂. Turn P₃ clockwise, when noise should become audible from the loudspeaker (or headphones). When S₁ is changed over, the noise level should increase or decrease (there is more noise when the superheterodyne section is on).

Set S₁ to COUNTDOWN and P₁ to maximum sensitivity. Rattle a set of keys in front of the microphone; this should produce a fairly loud noise in the loudspeaker.

With the detector near an operating TV receiver or computer monitor, a continuous whistle should be heard from the loudspeaker (try all positions of S₃). This is because the deflection coils or the line transformers in a TV receiver emit a continuous tone of 15625 Hz; that of a computer monitor is normally somewhat higher.

If the divider works correctly, set S₁ to SUPERHET. If a 455 kHz i.f. transformer is used in the L₂ position, adjust the inductance with a frequency meter as described later for L₁ or by listening to the loudspeaker: when L₂ is adjusted, the noise increases and its tone changes from high to low and then to high again. The correct setting is at the low tone. If a 452 kHz ceramic resonator is used in the L₂ position, this adjustment is not necessary.

Turn P₂ to check whether the oscillator in IC₃ can be tuned to 455 kHz. At that point, a whistle going from high to low and then to high again becomes audible. In the prototype, this happened with P₂ completely anticlockwise and the core of L₁ almost at its top position. With P₂ completely clockwise,

the oscillator frequency was 755 kHz.

If these results can not be obtained, the oscillator frequency is almost certainly too high. This may be remedied by lowering the value of R₂₃ (down to 0 Ω if need be). If this still does not give the desired result, a frequency meter should be used to determine at which frequency the oscillator does work and over what range it can be tuned.

Note that although the calibration may be carried out by ear, it is always better to do it with the aid of a frequency meter. Couple this meter loosely to L₁ or L₂ via a 10–100 pF capacitor. Adjust the core of the relevant inductor to obtain the correct frequency.

Parts list

Resistors:

R₁, R₆, R₁₁, R₁₆ = 1 k Ω
 R₂, R₇, R₁₃ = 150 k Ω
 R₃, R₈, R₁₄ = 27 k Ω
 R₄, R₉, R₁₂, R₂₄ = 47 Ω
 R₅, R₁₅, R₁₇ = 10 k Ω
 R₁₀, R₁₈ = 4.7 k Ω
 R₁₉ = 22 k Ω
 R₂₀ = 100 Ω
 R₂₁ = 100 k Ω
 R₂₂ = 8.2 k Ω
 R₂₃ = 1.8 k Ω (see text)
 P₁, P₂ = 10 k Ω , linear
 P₃ = 4.7 k Ω , logarithmic

Capacitors:

C₁, C₃, C₄, C₆, C₇, C₁₀–C₁₃, C₁₆, C₁₉,
 C₃₀ = 100 nF
 C₂, C₅, C₉, C₁₇ = 10 nF
 C₈, C₂₇ = 100 μ F, 25 V, radial
 C₁₄, C₁₈, C₂₆ = 1 nF
 C₁₅, C₂₁ = 33 nF
 C₂₀ = 220 nF
 C₂₂ = 470 pF
 C₂₃ = 1.8 nF
 C₂₄ = 22 nF
 C₂₅ = 4.7 nF
 C₂₈ = 47 μ F, 16 V, radial

Inductors:

Note: if i.f. transformers are used, see text about disabling the integral capacitor.

L₁ = LP4200A/93309 (Toko = Cirkit)
 L₂ = as L₁ or 452 kHz ceramic filter.

Semiconductors:

D₁, D₂ = varactor Type BB212
 D₃ = LED, yellow
 T₁–T₃ = BC550C

Integrated circuits:

IC₁ = 4024
 IC₂ = 4805 (or 7805 - see text)
 IC₃, IC₄ = NE612 (or NE602)
 IC₅ = TDA7052

Miscellaneous:

S₁ = double-pole change-over switch
 S₂ = single-pole on/off switch
 S₃ = single-pole, four-position (rotary)

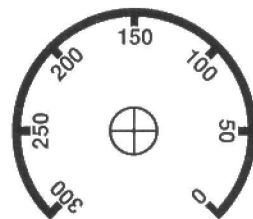


Fig. 8. Suggested frequency scale for P₂.

switch

S₄ = push-button switch with make contact

Mic₁ = electret microphone

Fl₁ = 455 kHz i.f. filter

Ls₁ = loudspeaker, 8–16 Ω , 200 mW

K₁ = jack socket with break contact

Enclosure $188 \times 120 \times 57$ mm

($7\frac{3}{8} \times 4\frac{3}{4} \times 2\frac{1}{4}$ in) metal

Bt₁ = 9 V battery with clip

PCB Order No. 936046

[936046]

READERS SERVICES

Except in the USA and Canada, all orders, except for subscriptions and past issues (for which see below), must be sent BY POST to our Dorchester office using the appropriate form opposite. Please note that we can not deal with PERSONAL CALLERS, as no stock is carried at the editorial and administrative office.

Readers in the USA and Canada should send orders, except for subscriptions (for which see below), to Old Colony Sound Lab, Peterborough NH, whose full address is given on the order form opposite. Please include shipping cost according to total order value. For surface delivery in the USA, if order is less than \$50, include \$3; \$50+, \$4. For Canada surface, if less than US\$50, include US\$5; US\$50+, US\$7.50. For air or other deliveries, please inquire. Please allow 4-6 weeks for delivery.

All other customers must add postage and packing charges for orders up to £25.00 as follows: UK and Eire £1.95; surface mail outside UK £2.45; Europe (airmail) £2.95; outside Europe (airmail) £3.70. For orders over £25.00, but not exceeding £100.00, these p&p charges should be doubled. For orders over £100.00 in value, p&p charges will be advised.

SUBSCRIPTIONS & PAST ISSUES

Subscriptions and past issues, if available, should be ordered from **Worldwide Subscription Service Ltd, Unit 4, Gibbs Reed Farm, Pashley Road, TICEHURST TN5 7HE, England**. For subscriptions, use the order form on the opposite page.

Prices of past issues (except July/August and December), including postage for single copies, are £2.70 (UK and Eire); £3.00 (surface mail outside UK); £3.20 (air mail Europe); £3.95 (airmail outside Europe). Prices of past July/August and December issues, including postage for single copies, are £3.75 (UK); £4.00 (surface mail outside UK); £4.25 (airmail Europe); and £5.00 (airmail outside Europe).

PAST ARTICLES

For information on past articles, please contact our Editorial and Administrative Office at Dorchester (telephone 01305 250995; fax 01305 250996).

COMPONENTS

Components for projects appearing in *Elektronics* are usually available from appropriate advertisers in this magazine. If difficulties in the supply of components are envisaged, a source will normally be advised in the article. It should be noted that the source(s) given is (are) not exclusive — other suppliers may also be able to help.

BOOKS

For book availability, see advertisement on page 81.

SLIPCASE

Elektronics slipcase£2.95\$6.00

PRINTED CIRCUIT BOARDS / SOFTWARE / FRONT PANEL FOILS / COMBINATIONS

Article title	Order no.	Price (£)	Price (US\$)	Article title	Order no.	Price (£)	Price (US\$)
APRIL 1995				- PCB + disk (946204-1)	940093-C	21.50	43.00
Electronic barometer	936033	8.50	17.00	- examples on PC disk	946204-1	9.75	19.50
Bat detector	936046	10.25	20.50	NOVEMBER 1994			
Sun blind control	950035-1	9.25	18.50	Single-wire communication	940055-1	4.00	8.00
Function generator:				In-car audio amplifier (2)	940078-2	30.25	60.50
- PCB + front panel foil	950044-C	21.75	43.50	Solid-state disk:			
- PCB	950044-1	11.00	22.00	- PCB + EPROM (946641-1)	940085-C	47.50	95.00
- Front panel foil	950044-F	12.50	25.00	- EPROM 27256	946641-1	23.50	47.00
Stepper motor control:				Simple capacitance meter	940091-1	10.00	20.00
- PCB + 8751 + disk	950038-C	50.75	101.50	OCTOBER 1994			
- 8751	956503-1	35.25	70.50	Motive-battery charger	940083-1	7.25	14.50
- test program on PC disk	956004-2	3.75	7.50	Integrated AF amplifier:			
MARCH 1995				- output amplifier PCB	936062-1	9.50	19.00
Telephone-controlled mains switch:				- preamplifier PCB	936062-2	28.25	56.50
- PCB + PIC (946642-1)	950010-C	22.00	44.00	Tester for IR remote control	940084-1	6.50	13.00
- PIC 16C54	946642-1	17.50	35.00	In-car audio amplifier (1)	940078-1	14.00	28.00
DSP function generator:				TV line monitor:			
- PCB + disk (956001-1) +				- PCB + PIC (946643-1)	940065-C	26.25	52.50
EPROM (956501-1)	950014-C	49.00	98.00	- PIC 16C54	946643-1	20.25	40.50
- EPROM 27C512	956501-1	13.25	26.50	SEPTEMBER 1994			
- software on IBM PC disk	956001-1	18.50	37.00	Switchable a.c. supply	934004	6.50	13.00
- Windows program manual	950014-P	7.50	15.00	Anemometer & flow meter	940017	6.25	12.50
TDA1560Q car audio amplifier	950024-1	9.50	19.00	Compact frequency meter	940051-1	9.00	18.00
FEBRUARY 1995				Revolution counter:			
MIDI multiplexor	930101	15.00	30.00	- sensor board (option)	940045-1	6.00	12.00
Automatic lighting timer	940098-1	10.75	21.50	- main board	940068-1	5.50	11.00
Infrared dimmer	940109-1	9.75	19.50	JULY/AUGUST 1994			
Light-effects generator	940100-1	6.50	13.00	General purpose IR volume			
Upgrade your car battery				control	930099	9.00	18.00
charger	940111-1	7.00	14.00	IR controlled switch	936066	9.75	19.50
Surround sound processor	950012-1	18.75	37.50	MIDI swell pedal:			
Induction motor governor	940095-1	7.50	15.00	- PCB + EPROM (946635-1)	940019-C	26.75	53.50
JANUARY 1995				- EPROM 27C64	946635-1	13.75	27.50
Mini Audio DAC	940099-1	14.75	29.50	Charge meter	940033-1	5.75	11.50
1-to-3-phase converter:				Water softener	940011-1	6.00	12.00
- PCB + GAL + EPROM	940077-C	52.75	105.50	Joystick-to-mouse adaptor	944040-1	7.00	14.00
- GAL	946640-1	12.25	24.40	Discrete preamplifier	944063-1	8.50	17.00
- EPROM	946640-2	15.75	31.50	Centronics I/O interface	944067-1	8.75	17.50
P.O.S.T. diagnostic card:				80C451 controller board	944069-1	15.00	30.00
- PCB + GALs (946639-1/2)	950008-C	29.25	58.50	Robust AF power amp	944075-1	9.75	19.50
- GAL-1	946639-1	11.00	22.00	PC over-temperature alarm	944076-1	4.25	8.50
- GAL-2	946639-2	13.00	26.00	1-4 MByte SIMM adaptor	944094-1	15.50	31.00
Self-loading EEPROM type				Optical doorbell	944080-1	6.25	12.50
X88C64 SLIC	940116-1	8.25	16.50	PIC experimenting board	944105-1	17.75	35.50
Debugging 8031/8051 micro-				RC5 transmitter with 80C535:			
controller systems:				- PCB + disk (946199-1)	944106-C	13.00	26.00
- PCB + disk (946203-1)	940117-C	15.00	30.00	- software on IBM PC disk	946199-1	9.75	19.50
- software on IBM PC disk	946203-1	11.50	23.00	A list of all PCBs, software products and front panel foils available through the Readers Services is published in the March, June, September and December issues of <i>Elektronics</i> .			
Quasi-analogue clockwork	930024	37.25	74.50				
DECEMBER 1994							
In-car audio amplifier (3)	940078-2	30.25	60.50				
RF immune power supply	940054-1	9.00	18.00				
ispStarter kit from Lattice:							

In resistor and capacitor values, decimal points and large numbers of zeros are avoided wherever possible. Small and large values are usually abbreviated as follows:

p (pico-)	= 10 ⁻¹²
n (nano-)	= 10 ⁻⁹
µ (micro-)	= 10 ⁻⁶
m (milli-)	= 10 ⁻³
k (kilo-)	= 10 ³
M (mega-)	= 10 ⁶
G (giga-)	= 10 ⁹

Examples:
2kΩ21 = 2.21 kΩ = 2,210 Ω
2µF2 = 2.2 µF
6V3 = 6.3 V

Note that nano-farad (nF) is the international way of writing 1000 pF or 0.001 µF. The international letter symbol 'U' is used for voltage instead of the ambiguous 'V'. The letter 'V' is reserved for 'volts'.

Resistors are 0.5 watt, 5% metal film types unless otherwise specified. 1% and 0.1%

tolerance types have values selected from the E96 range (IEC publication 63).
Resistor colour codes

Value	Multipplier (Q)	Tolerance	Temp. coefficient (10 ⁻⁶ /°C)
silver	0.01	10%	
gold	0.1	5%	
black	0	1	200
brown	1	10	100
red	2	100	50
orange	3	1k	15
yellow	4	10k	25
green	5	100k	0.5%
blue	6	1 M	0.25%
violet	7	10M	0.1%
grey	8		
white	9		1

Capacitors: the direct working voltage of capacitors (other than electrolytic or tantalum types) is assumed to be ≥50 V. As a rule of thumb, a safe value is about 2x the direct supply voltage. Unless otherwise stated, general-purpose polycarbonate types are used for values ≥1nF, and ceramic types for values <1 nF.

MKT = metallized film, polyethylene-terephthalate (PETP) (Siemens).

MKP = metallized film, polypropylene (PPN) (Siemens).

Styroflex™ = polystyrene (Siemens).

Sibaflex™ = low-loss ceramic (Siemens).

The working voltage of electrolytic capacitors stated in the parts lists is minimum. Types with a higher working voltage may be used if they fit on the relevant PCB.

Radial = single-ended; for vertical mounting.

Axial = wires at both sides of the device; for horizontal mounting.

Unless otherwise stated, axial types are used.

Direct test voltages are measured with a 20 kΩ/V meter unless otherwise specified.

Mains (power line) voltages are not normally listed in the articles. It is assumed that our readers know what voltage is standard in their part of the world.

Mains frequency: readers in countries that use 60 Hz supplies, should note that our circuits are usually designed for 50 Hz. This will not normally cause problems, although if the mains frequency is used for synchronization, some modification may be required.

Metric sizes: the size of a metric bolt or screw is defined by the letter M followed by a number corresponding to the overall diameter of the thread in mm, the x sign and the length of the bolt or screw, also in mm. For instance, an M4x6 bolt has a thread diameter of 4 mm and a length of 6 mm. The overall diameter of the thread in the BA sizes is: 0 BA = 6.12 mm; 2 BA = 4.78 mm; 4 BA = 3.68 mm; 6 BA = 2.85 mm; 8 BA = 2.25 mm.

SUN BLIND CONTROL

Design by A. Gessler



Sun blinds, whether of the traditional awning kind or of the modern metal roller type, provide welcome shade in the summer and, in the case of the latter, also good protection against break-ins. Many of these blinds are operated by an electric motor. The control described closes the blinds when it gets dark outside and opens them again when daylight returns. This automatic operation can be overridden by a manually operated switch, so that the blinds can be opened or closed at any time of the day as required.

The control unit can be added to the sun blind system without the need for modifications of any kind to the system.

The circuit (**Fig. 2**) is actuated by sensor IC₁, which converts the amount of light it receives into a direct voltage. This opto-IC, a Type TSL251 from Texas Instruments, is very sensitive and, because of an integral lens, fairly directional. Its spectral sensitivity lies in the region of 600–900 nm.

The output voltage of the sensor is compared with a reference voltage in IC_{2a}. The output of this comparator goes high when the light input is high, and low with little incident light. The change-over point is set with P₁. Resistors R₁ and R₂ provide the comparator with sufficient hysteresis to prevent the stage from clattering around the change-over point.

The output of IC_{2a} is compared in XNOR IC_{3a} with the value stored in bistable (US: flip-flop) IC_{6a}. When a

new situation has arisen (it has become light after dark or it has become dark after daylight) the output of IC_{3a} changes from logic 0 to 1. The consequent leading edge triggers monostable IC_{4a}. When the mono time of 10 min has elapsed, IC_{4a} generates a clock pulse for bistables IC_{6a}, which then stores the actual light intensity, and IC_{6b}, in which a 1 is placed if there was a change in condition. If there was no change, for instance, because the variation in light intensity had disappeared before the mono time had elapsed, a 0 is placed in IC_{6b}.

When there is a 1 in IC_{6b}, its Q output is high, and this actuates monostable IC_{4b}. For a preset period of not less than 1.5 s and not more than 2 m, output Q of IC_{4b} is low. At the same time, and during the same period, the output of IC_{5b} is high, which causes relay Re₂ to be energized via T₂. The manual control of the sun blind motor is then disabled and the pole of Re₁ is connected to the L(ive) wire of the mains. Depending on the state of the relay, the sun blind will then be lowered or raised. The period during which the motor is energized is determined by IC_{4b}. It is important that this period is longer than the time taken by the blind to be lowered or raised completely. If it were shorter, the motor would be deenergized before the wanted setting of the blind had been reached. A longer period does not matter, because the end-stop switches of the sun blind system cause the motor to be deenergized when the blind has been completely lowered or raised. After the mono time of IC_{4b} has elapsed, Re₂ is deenergized, whereupon the blind can be lowered or raised by manual control again.

The circuit has a second input via

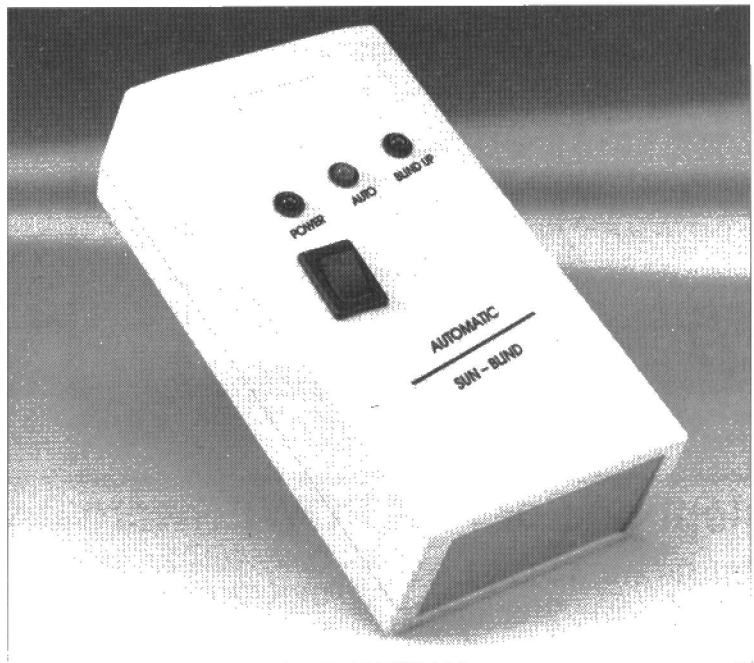
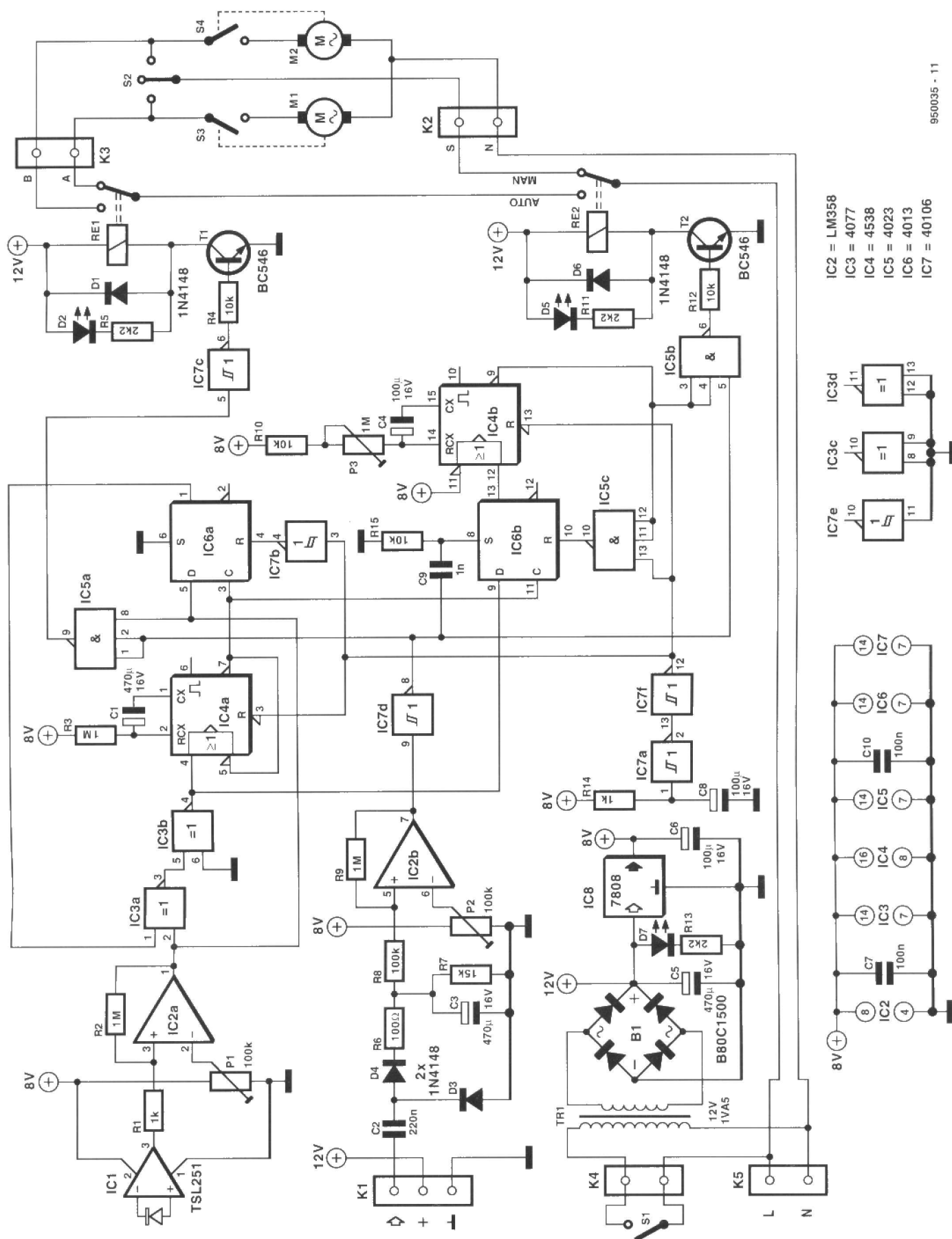


Fig. 1. General view of the sun blind control unit.

K_1 . This input is intended to be connected to an anemometer: the values of the components specified allow a stan-

dard type to be used. The sensitivity of the input is about $1 \text{ V } 100 \text{ Hz}^{-1}$. The change-over point of comparator IC_{2b} is

set with P_2 . The hysteresis of the comparator may be reduced by enlarging the value of R_9 .



950035 - 11

Fig. 2. Circuit diagram of the sun blind control.

When an anemometer is connected to K_1 and the wind speed increases to, say, force 4 to 5 on Beaufort scale ($18\text{--}23\text{ km h}^{-1}$), the output of IC_{2b} is high, otherwise it is low.

Since the output of IC_{2b} is inverted before it is applied to AND gates IC_{5a} and IC_{5b} , the quiescent signal does not affect the operation of the remainder of the circuit.

A high logic level at the output of IC_{2b} supersedes all other control signals in the circuit. It causes the manual operation to be disabled and the sun blind to be raised to prevent its being damaged by the strong wind. Only when the wind has moderated will the signal go low again. Bistable IC_{6b} is then reset via C_9 and R_{15} , whereupon IC_{4b} receives a start pulse and the sun blind is lowered if there is still sunshine. If not, the blind remains raised.

The circuit also has a common reset network: immediately after the mains has been switched on, IC_{7a} generates a reset pulse. This pulse sets monostables IC_{4a} and IC_{4b} and bistables IC_{6a} and IC_{6b} to their starting state, so that manual control is available.

Construction

The sun blind control is intended to be built on the printed-circuit board in **Fig. 3**. Start with the small passive components, followed by the larger ones, then the active devices, and finally the mains transformer, the relays and the terminal strips. When the board is finished, it should be mounted in an ABS (or other tough man-made fibre) enclosure measuring about $130 \times 80 \times 35\text{ mm}$ ($5\frac{1}{8} \times 3\frac{1}{8} \times 1\frac{3}{8}\text{ in.}$).

The LEDs must be mounted on the

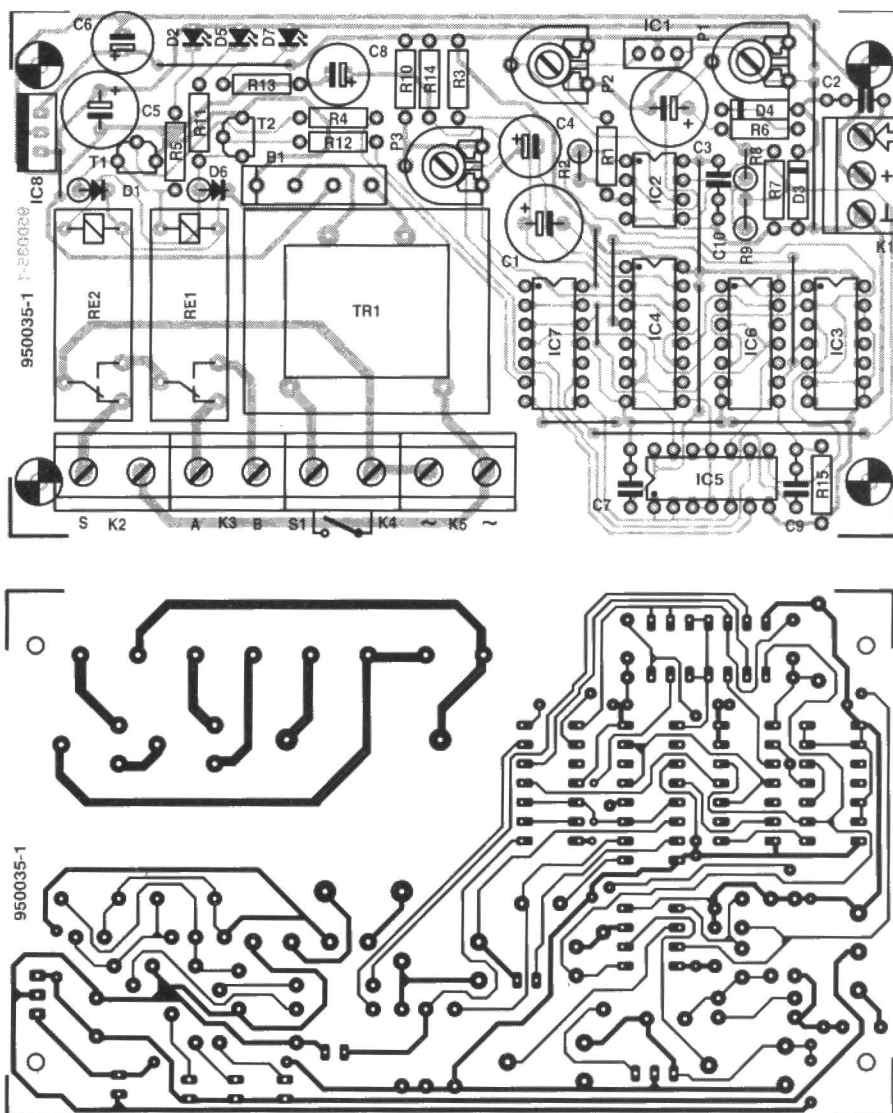


Fig. 3. Printed-circuit board for the sun blind control.

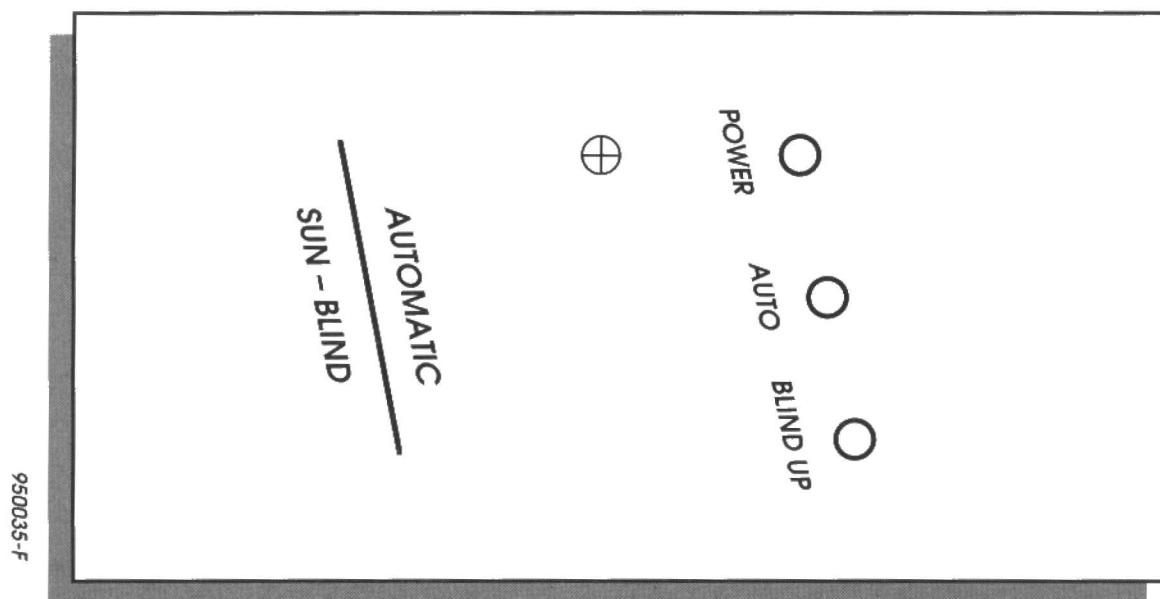


Fig. 4. Suggested front panel for the sun blind control (foil not available ready-made). Scale 1:1.



IF AN ADVERT IS WRONG, WHO PUTS IT RIGHT?

We do. The Advertising Standards Authority ensures advertisements meet with the strict Code of Advertising Practice.

So if you question an advertiser, they have to answer to us.

To find out more about the ASA, please write to
Advertising Standards Authority,
Department X, Brook House,
Torrington Place, London WC1E 7HN.



This space is donated in the interests of high standards in advertisements.

BADGER BOARDS

Printed Circuit Boards for Amateur Radio Schools Colleges
Short Wave Listeners Clubs Hobbyists & Industry

A range of Printed Circuit Boards in stock from many of the Projects in Magazines
PRACTICAL WIRELESS □ SHORT WAVE MAGAZINE □ ELEKTOR □ HRT
RADIO COMMUNICATION

Kits Projects and Materials for manufacturing your own boards. Artwork and Plotting from your own Schematic drawings and also C.A.D. facilities. We supply ONE OFF Prototypes
Phone between 9.00am and 5.30pm Monday to Friday for helpful advice and assistance
Club talks and demonstrations of Printed Circuit Board manufacture QRP involvement etc

0121 - 384 2473

80 Clarence Road, Birmingham B23 6AR

(Please mention where you spotted this advertisement)

front panel of the enclosure.

The enclosure must be provided with a hole in such a position that the sensor can 'see' the outside light from the correct direction.

If the wind protection facility is not required, C₂, C₃, D₃, D₄, R₆, and K₁ can be omitted.

LED series resistors R₅, R₁₁, and R₁₃ have the right value for high-efficiency LEDs. If these diodes are not bright enough, the value of the resistors may be lowered to 470 Ω. Diode D₅ indicates for how long the motors are energized during the lowering and raising of the blind; D₂ shows whether the blind is being raised or lowered; D₇ is the on/off indicator.

A suggested front-panel layout is given in Fig. 4.

Installation

Remove the mains from the electrical system of the sun blind (best done by removing the relevant mains fuses from the fuse box).

Undo the L(ive) mains wire from the manual switch (S₂ in Fig. 2) of the sun blind system and link the freed switch terminal to terminal S of K₂ as shown in Fig. 2.

Connect K₅ to the L(ive) and N(eutral) of the mains as indicated in Fig. 2.

Figure 2 shows two motors for operating the blind; in practice there is normally only one motor with separate connections for clockwise and anti-clockwise rotation.

Before the control unit is connected to the sun blind system, check that the

system has end-stop switches (as far as is known, these are always fitted). In the unlikely case that there are no such switches, the control unit can not be used, since there is then a risk of the motor burning out in certain circumstances.

The control unit has no fuse, since it is assumed that all sun blind systems already have one. If there is not, a fuseholder with 1.5 A fuse may still be added in side the control unit.

Setting up

Set P₂ to the centre of its travel and adjust P₁ so that the control unit reacts to the desired level of incident light. D₂ shows when the control changes over from light to dark and vice versa.

Set P₃ for the wanted running time of the motor. At the end of this period, the manual control must be reenabled.

If the blind moves into the wrong direction (up instead of down or vice versa), interchange connections A and B at K₃ (at one side only).

If an anemometer is used, wait until the wind is of a strength that is considered possibly damaging to the sun blind and then turn P₂ until the circuit just reacts and the sun blind is raised.

Parts list

Resistors:

R₁, R₁₄ = 1 kΩ
R₂, R₃, R₉ = 1 MΩ
R₄, R₁₀, R₁₂, R₁₅ = 10 kΩ
R₅, R₁₁, R₁₃ = 2.2 kΩ (see text)
R₆ = 100 Ω

R₇ = 15 kΩ
R₈ = 100 kΩ
P₁, P₂ = 100 kΩ preset
P₃ = 1 MΩ preset

Capacitors:

C₁, C₃, C₅ = 470 μF, 16 V, radial
C₂ = 220 nF
C₄, C₆, C₈ = 100 μF, 16 V, radial
C₇, C₁₀ = 100 nF
C₉ = 1 nF

Semiconductors:

D₁, D₃, D₄, D₆ = 1N4148
D₂, D₅, D₇ = LED, high efficiency
T₁, T₂ = BC546
B₁ = B80C1500

Integrated circuits:

IC₁ = TSL251 or TSL250 (Texas Instr)
IC₂ = LM358
IC₃ = 4077
IC₄ = 4538
IC₅ = 4023
IC₆ = 4013
IC₇ = 40106
IC₈ = 7808

Miscellaneous:

K₁ = 3-way terminal strip, pitch 5 mm
K₂-K₅ = 2-way terminal strip, pitch 7.5 mm
S₁ = mains on/off switch
Re₁, Re₂ = 12 V relay with contacts rated for mains voltage operation
Tr₁ = mains transformer, secondary 12 V, 1.5 A (e.g., Velleman 1120018M - Maplin)
PCB Order No. 930035
Enclosure - see text

[930035]

NEW

FULL COLOUR GUIDE TO ELECTRONIC PRODUCTS

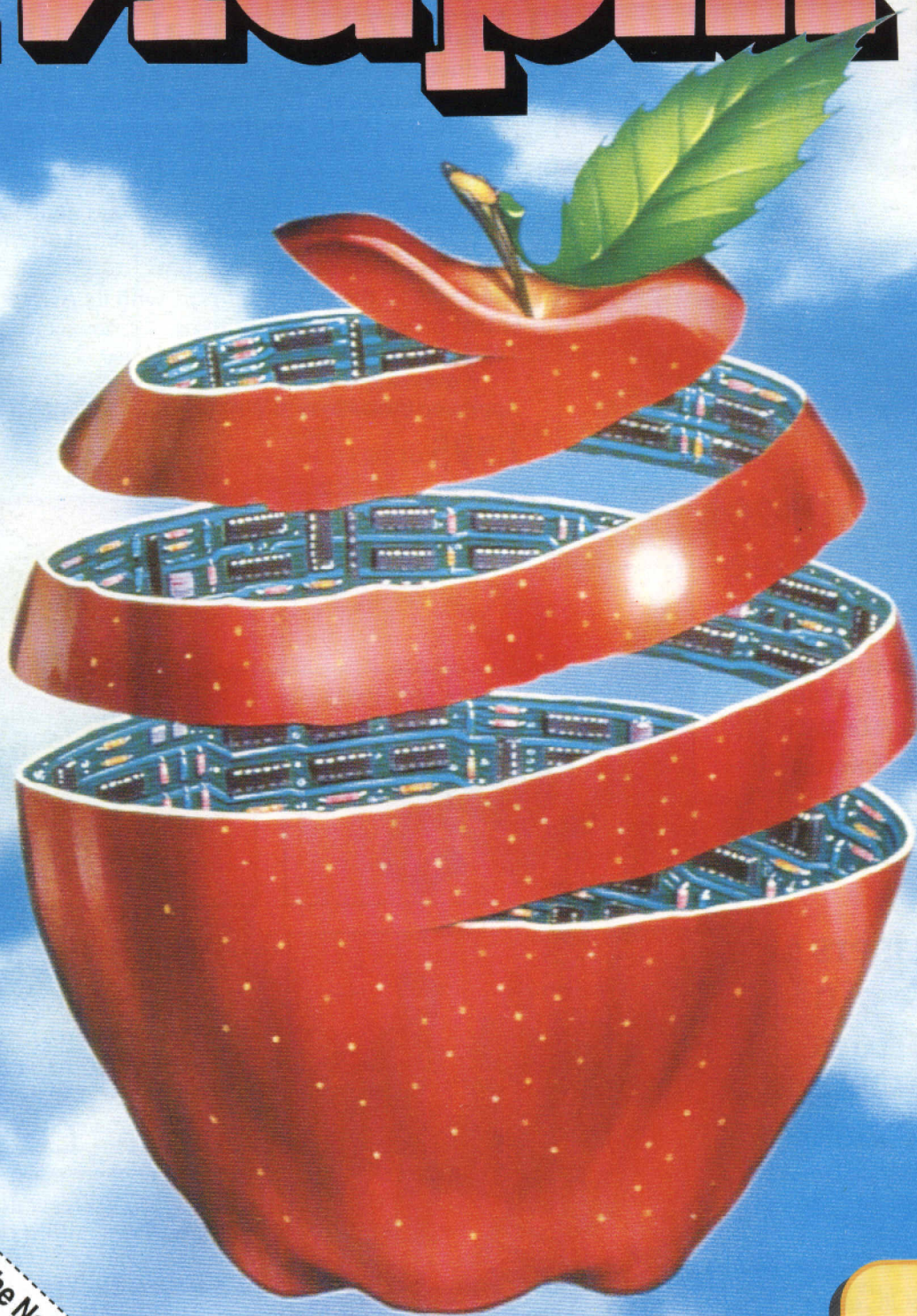
Sept 1994–Aug 1995

Maplin



BS 5750
Part 2 1987

Level B:
Quality Assurance
RS12750



Order your copy of the New MAPLIN Catalogue on sale NOW

Pick up a copy from any branch of WHSMITH, branches of John Menzies in Scotland ONLY, Eason & Son in N. Ireland ONLY, and Maplin stores nationwide for just £3.45 inc. p&p. If you live outside the U.K. send £7.30 or 18 IRCs to receive your copy for just £3.95 inc. p&p. If you live outside the U.K. send £7.30 or 18 IRCs for surface mail for Airmail in Europe (including Republic of Ireland); £6.50 or 16 IRCs for Airmail outside Europe. I enclose £3.95/£7.30/£6.50/£12.30 (delete as applicable).

Name

Address

Post Code

Send to Maplin Electronics,
P.O. Box 3, Rayleigh,
Essex, England
SS6 8LR
UK95

**Over 800 colour packed pages
with hundreds of Brand New
Products at Super Low Prices.**

**OUT OF
THIS WORLD
ONLY
£3.45**

Available from all branches of WHSMITH, John Menzies in Scotland ONLY, Eason & Son in N. Ireland ONLY, and Maplin stores nationwide.
The Maplin Electronics 1995 Catalogue – **OUT OF THIS WORLD!**